Energy audit of Modern Food Industries (I) Ltd. Bread Unit I, New Delhi

Prepared for **Hindustan Lever Ltd., Modern Food Industries (I) Ltd., New Delhi**

T E R I Project Report No. 2002IE61

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Energy audit of Bread Unit I at Modern Food Industries (I) Ltd., New Delhi

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Project Team
Mr Debashish Pramanik
Mr Kaushik Bhattacharjee
Mr Kulbhushan Kumar
Mr Puneet Katyal

For more information about this report, please contact

Industrial Energy Group
TERI
Darbari Seth Block
Habitat Place, Lodhi Road
New Delhi – 110 003 / India

Telephone +91 11 468 2100 or 468 2111
E-mail mailbox@teri.res.in
Fax +91 11 468 2144 or 468 2145
Web site www.teriin.org

Contents

Executive summary .... i - vi

Chapter 1
Introduction .... 1 - 1

Chapter 2
Boiler and steam handling area/system .... 3 - 11

Chapter 3
Baking ovens, final provers and tunnel coolers .... 13 - 41

Chapter 4
Compressed air system .... 43 - 49

Chapter 5
Cooling Towers .... 51 - 54

Chapter 6
D G sets .... 55 - 61

Chapter 7
Demand management and power factor .... 63 - 69

Chapter 8
Electric motors .... 71 - 73

Chapter 9
Lighting .... 75 - 79

Annexures .... i - xiv

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Executive Summary

At the instance of Modern Food Industries (I) Limited, Delhi Bread Unit 1 (MFIL), New Delhi, a comprehensive energy conservation study was carried out by Tata Energy Research Institute (TERI), New Delhi. The main aim of the energy conservation study was to make detailed study of the utility areas, identify potential areas of energy conservation and recommend energy savings measures along with cost benefit analysis of the same. The executive summary highlights the major findings and recommendations of the energy audit.

The energy audit study covers the following systems to identify energy conservation opportunities.

- Baking ovens, final provers and cooling tunnels
- Boiler and steam handling system
- Compressed air systems
- Cooling towers
- DG sets
- Electric motors
- Lighting
- Demand management and power factor
- Refrigeration and Air-conditioning

The main report contains detailed analysis and recommendations emerging from the study of the unit. A summary of the major recommendations has been given in the following sections.

Baking ovens, final provers and Cooling tunnels

There are three ovens for drying, baking the breads/ loaves operating in the unit. Light diesel oil (LDO) is used as fuel in the ovens. During the time of the energy audit, it was found that two ovens (no.1 and no. 3) were in operation. Heat balance and annual savings is worked out for two ovens.

- The available energy or efficiency of the oven no.1 and no. 3 is evaluated to be about 47.87% and 32.34% respectively, which is not satisfactory.

- Very high average level of excess air 244.3% was measured at the first stage in the oven 2. The savings achievement because of the first stage manual adjustment and reduction (up to 55.6%) of excess air could be anticipated around Rs. 5.5 lacs per annum. High average level of excess air 90% and 55.6% (after first stage) was measured in the oven 1 and 2 respectively. Optimisation of it in the oven 1 and 2 would result in the further saving of Rs.3.57 lacs and Rs.0.78 lacs per annum.

- High flue gas (average) temperature 308°C and 189°C was measured in the oven 1 and 2 respectively. There is also a possibility of temperature reduction, additional heat recovery from flue gases by regular soot cleaning, secondary coil replacing and best operating HRS in oven 1 and 2, which would fetch a saving of Rs.0.4 lacs per annum and Rs.0.078 lacs per annum. It is suggested to contact the HRS manufacturer before coil replacement.

- The temperature of following selective surfaces in two ovens was above the permissible limit. The average temperature of the top, upper front segment (LH & RH) in oven 1, front & rear segment of LH and RH in oven 2 is 67°C, 74.3°C& 71°C and 73.4°C, 72.7°C, 71°C, 77.8°C respectively. It is recommended to replace the damaged mineral wool insulation with the ceramic board of 2 inches inside and remaining mineral wool. It will give an annual saving in oven #1 and #2 of approximately Rs. 0.89 lacs and Rs. 0.99 lacs respectively. The approximate investment required is Rs 6250 and 5900 with a simple payback period of 1 month and 1 month respectively.

Boilers and steam handling system

There are three package boilers and one tiny/ small boiler operating in the unit. Light diesel oil (LDO) is used as fuel in the boilers. During the time of the energy audit, it was found that two package boilers and one small boiler were in operation. The performance of the boilers has been studied.

- By running the boiler 2 and 3 with optimum excess air level (low) 20-22% would result in an annual fuel saving of 6.28 tonnes (7.39 kL) or Rs 1.1 lacs and 4.84 tonnes (5.69 kL) or Rs 0.84 lacs respectively.

- High flue gas temperature 243°C and 176°C is measured in the boiler 2 and 3. By regular soot cleaning, the flue gas temperature could be reduced. It will result in to the annual saving of Rs. 0.44 lacs and Rs. 0.06 lacs respectively.

- TDS of blowdown in the boilers was found to be 300 ppm. It is recommended to blowdown boiler at the TDS limit of 3500 ppm. It will result in to the annual saving in boiler 2 and 3 of Rs. 0.38 lacs and Rs. 0.25 lacs respectively.

Compressed air systems

There are four numbers of reciprocating type air compressors (no. 1, no. 2, no. 3 and no. 4) in the unit. Three (no. 1, no. 2 and no. 3) of them were tested for the free air discharge (FAD). The designed FAD of the four compressors is 0.57 m^3/min, 0.57 m^3/min and 0.57 m^3/min respectively. The performance of three compressors, overall leakage in the distribution system and the leakage points has been studied.

- The actual FAD of four compressors (no. 1, no. 2 and no. 3) is 0.559 m^3/min, 0.555 m^3/min and 0.463 m^3/min respectively.

- Presently the leakage rate in the compressed air distribution system is 40.5%. It is recommended to plug the leakage in the compressed air line. It offers significant energy savings with very small investment. Annual energy savings of 5016 kWh or Rs 0.233 lacs can be achieved by almost without investment.

Cooling towers

There are three numbers of cooling towers operating to meet the cooling water requirement of three air-conditioning units. Out of 3 towers, two were tested for the performance analysis. The cooling towers (no. 1 for 15 TR, no. 2 for 20 TR and no. 3 for 40 TR) are single cell induced draft type.

- Ensure proper maintenance of the existing fills of cooling tower no. 3 to avail maximum water exposed surface area to air. It offers excellent level in the performance.

- The fan blades of two cooling towers are made of aluminium. The aluminium blades should be replaced by hollow FRP blades in the cooling tower fans. This measure will save electricity in cooling towers to the tune of 504 kWh and 1007 kWh per year. The investment required for each fan is Rs. 9000-12000 /-. The simple payback period for cooling tower no. 1 is not attractive. The payback period for the cooling tower #3 would be about 2 years and 6 months.

- The electronic thermostatic controllers should be installed for cooling tower no. 1 and no. 3 fan motor circuit in air conditioning units. This switches off the fan automatically when water temperature in the basin is lower than 22^{0}C (during the month of winter and hours of low ambient temperature in some of the months in the year. These are November (last half), December, January, February, March (first half) and night of April (first half), September and October). This measure yields the annual savings of 1623 kWh (Rs. 7550) and 3245 kWh (Rs. 15100). The investment required is Rs 18000 per piece of controller with the simple payback period of 2 years 5 months and 1 year 2 months respectively.

DG sets

There are three Diesel generating (DG) sets operating in the unit. The rated capacity of these sets is 250 kVA, 250 kVA and 63 kVA respectively. The loading range on set 1 and 2 is between 27-75% and 20-75% respectively.

- Irrespective of the number of DG sets in operation, the sets should be loaded to the optimum level (80 percent). This will ensure the best operating condition of the sets.
- It is recommended to perform the Specific Energy Generation Ratio (SEGR) test of the DG sets. The actual SEGR of the sets should be close to the designed level recommended by the manufactures.

Demand management and power factor

Reducing the contract demand from 460 kVA to 350 kVA would lead to savings of Rs.1.98 lacs per annum.

The average power of the plant is varying between 0.94 to 0.98. The plant can save about Rs.83497 with an investment of Rs.80000 by maintaining the power factor close to 0.98.

Transformer

There are three transformers installed, two of 500 kVA rating each and one of 200 kVA rating, to step down the incoming power supply at 11 kV to 0.415 kV. It is recommended to load the 500 kVA transformers alternately and completely switch off 200 kVA transformer. This would lead to a savings of Rs.32,000/- per annum.

Electric motors

To evaluate the performance of motors and to see how they are loaded, load tests were conducted on 9 motors. Motor loading varied from a low of 39% for-oven recirculation fan-1 and 2 to as high as 85% for Mixer plant-1.

Use of efficient transmission system would reduce the energy consumption in motor by 5540 kWH. Which would lead to an annual savings of Rs.18837 with an investment of about Rs.20,000.

Lighting

The illumination level was measured at different locations. The illumination required depends upon the difficulty of the task to be performed and varies widely. It could be seen form the table that generally the illumination provided has been found to be less then recommended levels for various sections of the plant.

Replacement of 40W TL with 28W energy efficient lamp would reduce the energy consumption in lighting. This would amounts to a saving of Rs.107590. With an investments of Rs.2,34,400.

Table I. Summary of recommendations

Sl. No.	Suggested measure	Total annual savings		Investment (Rs Lacs)	Payback period (years/ months)
		(kL)	(Rs Lacs)		
1	Optimization of steam boilers - Oxygen, excess air and flue gas temperature	17.6	2.63	1.0	4.5 months
2.	Optimization of blow down in boiler	4.28	0.64	0.08	1.5 months
3.	Excess air optimisation by installing on-line O_2 analyser in the individual oven with maximum steam generation from HRS				
	- No.1 (90%-45%)	47.5	6.82	6	11 months
	- No. 2 (244.3%-55.6%)	36.7	5.47	6	11 months
	- No. 2 (55.6%-45%)	8.2	1.22		
	- using new efficient burners	N. Q	N. Q	--	---
4	Replacing insulation on selective side of two ovens	12.7	1.89	0.12	1 month
5	Use of thermostatic controller in cooling tower no. 3		0.11	0.18	1 year 7 months
6	Optimisation of drain interval in DG sets -for lube oil (using test kit)	--	--	0.3	--
7	Replacement of V-belts by flat belts		0.18	0.2 *	1.6 years
8	Use of energy efficient tube lights		1.07	2.3	2.2 years
9	Reduction of contract demand		1.98	Nil	Immediate
10	Power Factor improvement		0.83	0.8 *	0.95 year
11	Transformer loss		0.32	Nil	Immediate
	Total		**23.16**	**16.68**	

N.Q. – Not quantified, Quotation from supplier awaited
* Rough Estimate, quotation awaited.

1

Introduction

Comprehensive energy audit of the plant of Modern Food Industries (I) Limited, Delhi Bread Unit 1, at New Delhi was carried out by Tata Energy Research Institute (TERI), New Delhi, to study the operating efficiency of major energy consuming systems and to identify the energy saving possibilities. TERI team visited the unit in April 2002 to undertake measurements and for collection of data. Discussions were also held with the plant personnel to accomplish the task in the meaningful manner. Plant personnel asked for recommendation/ information in the following three categories.

1. Recommendations with negligible investment;
2. Recommendations with minimum investment;
3. Recommendations with higher investment.

Modern Food Industries (I) Limited (MFIL) is a leading manufacturer of breads/ loaves. MFIL, New Delhi is a continuous production complex/ unit. The processing unit has three identical production lines and ovens with similar kind of equipment. The oven I, II and III is used for the following variety of breads/ loaves production: 300 grams, 400 grams HV, 400 grams long, 400 grams classic gold, 600 grams, 800 grams Atta and 800 grams special.

Each line is consists of one final prover, one oven and one tunnel cooler. The changeover is done from one product to the other after thorough changing of bread/ loaf carrying tin containers and cleaning of the processing line. The line IV is not being used for drying, baking bread/ loaf since September 2001. The management has been trying to upgrade the existing plant facilities with the state-of-the-art techniques. The average installed capacity of each of the three lines is 40000 Sl (standard loaf) per day. The total installed capacity of three lines is 43.3 million Sl (standard loaf) per annum. The major fuel being used by the unit is LDO and HSD. There are two sources of power supply to the plant – DVB supply and the plant's own generation through diesel generator sets.

The focus of the present study was to carry out a detailed analysis of the major energy consuming equipments as given in the proposal submitted by TERI. A report covering each of these areas is given in the following chapters.

2

Boilers and steam handling area/system

There are four oil-fired steam boilers in the utility area of the unit. The number of package type and tiny/ small type boiler is 3 and 1 respectively. Under normal circumstances, two boilers were operated to meet the steam requirement of two final provers with the others serving as the standby. One tiny/ small boiler has been installed in the year 2001. Since then the small boiler is also operating to meet the steam requirement of oven in the plant. Primarily, the individual oven is coupled with the HRS for steam generation. Plant personnel reported that the quantity and pressure of steam available from the HRS is frequently not adequate and low. Moreover, the shut-down of HRS is also undertaken occasionally. Sometime, the requirement of steam from package/ small boiler becomes inevitable. Practically, the package/ small boiler is immediately operated to fulfil the shortage of steam (from HRS) in the final prover. Plant personnel have been proposing to run the tiny/ small boiler continuously based on the study/ review of reliability, safety aspect and reduce the package boiler operation. Steam is required for humidification process (adding moisture and heat to dough in prover) in the production line equipment of the plant. Steam is fully consumed in the humidification process. The breads/ loaves of seven different varieties are produced in the plant. Steam is required for 300 days in a year in the unit. Light diesel oil (LDO) is used as fuel in the boilers. During the time of the energy audit, it was found that the two package boilers and one small were in continuous operation. There is no flow meter for the measurement of oil, feed water and steam flow.

The make up water is treated in a softening unit. Proper conditioning of water results in: (1) freedom from deposits on internal surfaces, (2) absence of corrosion of internal surfaces, and (3) prevention of carry-over of boiler water solids into steam caused by forming and/or high total dissolved solids. The make up water alone comprises the feed water to the boilers. The feed water available through cylindrical optimiser and rectangular box type economiser in package boilers was estimated to be about 70.0°C temperature. To control the level of total dissolved solids (TDS) in the boiler water, intermediate blowdown is adopted. This operation is performed four times in every shift.

The following sections discuss the methodology adopted for evaluating boiler performance based on various measurements taken during the visit.

Detail of steam boilers

The package boiler is the fire tube and has three passes reverse flue passage. It is equipped with automatically/ manually operated forced draught and forced circulation system. The small boiler is the top covered, cylindrical drum like container and equipped with manually operated forced draught and forced circulation system. The detail of package boilers is given in Table 2.1. The details of small boiler are not available.

Table 2.1. Details of package boilers

Boiler No.	Make/Model	Generation capacity (kg/hr)	Design pressure (kg/cm^2)
1	Thermax/RXA 03	300	10.5
2	Thermax/RXA 04	400	10.5
3	Thermax/RXA 06	600	10.5

The fuel burner is situated at the top centre of the vertical spiral coil in each package boiler. The burner is pressure atomising, vertical firing, forced draught, with direct electric spark ignition. The modulation system of the burners is not working. During the study, it was found that the package boiler #2 and #3 was operating at fixed steam pressure of 6.5 kg/cm^2 (g) and 9.0 kg/cm^2 (g) respectively. The corresponding temperature was 179°C and 166.9°C respectively. Burner in the package boilers is switched off/ on at the high/ low set in pressures and temperature respectively. Package boilers are adjusted with the different cut-in/ cut-out level of pressure for the generation of steam. The burner stops firing when the steam pressure reaches a cut-out value set on the pressure gauge. The burner restarts as soon as the steam pressure drops to the cut-in set value. The combustion air fan and fuel oil pump is grouped at the base of the rectangular boiler unit. The combustion air/fuel flow to the boiler is not continuously controlled with the changing position of damper/valve. It is reported that the damper/valve function at fixed level of setting. During the study, it was found that the damper in the individual boiler is fixed between 35-50% open position. it was also found that the small boiler was operating between steam pressure of 1.5-2.5 kg/cm^2 (g).

Insulation of three packaged boilers and preheating of combustion air are achieved by circulating the combustion air through a double jacket (black coloured) formed by the inner shell and the outer shell with a radiator in between surrounding the combustion chamber. The small boiler surfaces are provided with 3 inches thick mineral wool insulation with aluminium cladding. The package boilers and small boiler are equipped with the safety valve systems. Feedwater come to boilers from the combined feed water tank. Operation of the feed water pump is contingent on package boiler loading and water level in the drum. Boiler #1 and #2 is fitted with the compact box type economiser. The temperature of feed water after individual economiser in boiler #2 and #3 at 66.8°C and 70°C respectively. Blowdown in the package boilers is carried out twelve times every day. The blowdown of package boiler water takes about 5-10 seconds time.

Performance of boiler

The performance of package/ small boiler can be assessed by determining their thermal efficiency. There are two methods to determine the efficiency of a boiler, direct method and indirect method. Direct method is based on the ratio of the output, to the sum of the fuel input. It requires measurement of the operating parameter and Gross Calorific Value (GCV) of the fuel and the heat absorbed by the steam generator. In these cases the steam flow rate of the boiler was not available, and hence efficiency could not calculated by direct method. It has, however, been evaluated using indirect method.

Methodology

In the indirect method, first various losses associated with the boiler are calculated and the thermal efficiency of boiler is determined as the difference between the heat input and sum of the heat losses associated with boiler. In the following sections, boiler efficiency and various losses are evaluated based on the data collected and measurement taken at site.

Boiler efficiency

Boiler efficiency by indirect method

The operating parameters required to evaluate the thermal efficiency of package steam boilers measured during the audit, and those derived from them are given in Table 2.2. The testing of parameter in small boiler was tried, but proper flue gases sample was not available in chimney.

Table 2.2. Operating parameters of boiler

Parameter	Boiler #2	Boiler #3
Oxygen in flue gas (%)	12.0	14.1
Carbon dioxide in flue gas (%)	6.7	5.1
Carbon monoxide in flue gas (%)	0.0136	0.0073
Temperature of flue gas (° C)	243	176
Dry bulb temperature (° C)	34	34
Steam pressure (kg/cm^2,g)	9.0	6.5
Steam temperature (° C)	179	166.9
Feed water temperature (° C)	70	66.8
Feed water TDS (ppm)	50	50
Blowdown TDS (ppm)	300	300

PPM: parts per million,

Heat balance of steam boiler

Heat input

The average fuel (LDO) firing rate for package boiler #2 and #3 is 14.0 kg/hr and 10.2 kg/hr respectively. The gross calorific value (GCV) and ultimate analysis of the fuel (LDO) being fed to the boiler is given in Table 2.3. The average fuel (HSD) firing rate for small boiler is reported to be 3 litres/ hr, after switching over from LDO in last few days. The total heat input to the boiler was arrived at by multiplying the fuel consumption rate with the average GCV value of the fuel.

Table 2.3 Ultimate analysis of LDO

Parameter	Furnace oil (LDO)
Carbon (%)	86.0
Hydrogen (%)	12.0
Oxygen (%)	–
Sulphur (%)	0.5
Moisture (%)	0.3
GCV (kcal/kg)	10200

Heat losses

As a part of efficiency evaluation by indirect method, a detailed heat balance was carried out which is enclosed in **annexure 2.1**. The various heat losses associated with the package boiler, which are considered for heat balance, are given below.

(i) Dry flue gas loss

(ii) Heat loss due to CO formation

(iii) Heat loss due to hydrogen and moisture in fuel
(iv) Heat loss due to moisture in air
(v) Heat loss due to blowdown
(vi) Structural and unaccounted heat loss

The summary of the results of the heat balance is given in Table 2.4. As can be seen from the table, the total heat loss associated with package boiler #2 and #3 is 29.29% and 26.52% respectively. Hence, the thermal efficiency is 70.71% and 73.48% respectively.

Table 2.4 Heat balance of the package boilers

Type of heat loss	Boiler #2	Boiler #3
Dry flue gas loss (%)	16.88	14.96
Loss due to moisture and hydrogen in fuel (%)	7.16	6.82
Loss due to moisture in air (%)	0.68	0.54
Loss due to carbon monoxide (%)	0.215	0.116
Loss due to blowdown (%)	3.35	3.08
Loss due to radiation and convection (%)	1.00	1.00
Total heat loss (%)	**29.29**	**26.52**
Thermal efficiency of boiler (%)	**70.71**	**73.48**

Analysis and recommendations

Based on the analysis of data collected and measurements made at site, areas to improve thermal efficiency are given below for the boiler. Sampling points for taking oxygen measurements in flue gases are already present in the boiler. The average fuel consumption was monitored. It has been considered for calculation of the average steam generation and annual savings. Plant personnel could not provide the average fuel consumption for last twelve months. The average steam generation for package boiler #2 and #3 has been estimated to be 170.5 kg/hr and 128.8 kg/hr respectively. The thermal efficiency and average steam generation of small boiler could not be calculated. The annual saving for individual package boiler has been calculated considering 20 hours operation for 150 days in a year.

Dry flue gas loss

It is clear from the Table 2.4 that dry flue gas loss is one of the major loss among the all losses calculated for the boiler. There are two factors contributing to this loss and optimization of these can substantially reduce it. These factors are (i) excess air and (ii) flue gas temperature. These are discussed in detail below.

Excess air optimisation

To achieve a high thermal efficiency, thereby minimising fuel costs, the amount of combustion air required should be limited to that necessary to ensure complete combustion of oil at all times. For oil firing an excess air level of 20-30 % is necessary to ensure that complete combustion takes place. This corresponds to oxygen content of 3.5 - 4.8% in the flue gas. The package boiler #2 and #3 is found to operate at an excess air level of about 133% and 204% respectively. Operating the boiler at excess air optimum level (low) will give significant annual savings. The annual saving of approximately Rs. 1,10,300 and Rs. 84,900 can be achieved in the package boiler #2 and #3. Detail of calculations is provided in the **annexure 2.2**.

Flue gas temperature

During the study, the variation in the flue gas temperatures was observed. The exit flue gas temperature for the package boiler #2 and #3 was found to be 243^0 C and 176^0 C respectively.

The flue gas temperature in the boilers is higher which could be due to soot deposition inside the flue gas tubes or scale deposition on the out side of the tubes or both in the boiler due to long run, which reduces the heat transfer to the water. However, it is felt that boilers cleaning will reduce this temperature by 20-30°C. The annual saving of approximately Rs. 44,300 and Rs.6,200 can be achieved in the package boiler #2 and #3 as given in the **annexure 2.2**.

Heat loss due to CO

The carbon monoxide (CO) level indicates the level of combustion. Therefore, CO level should be as minimum as possible to achieve better combustion efficiency. The loss due to CO in the boiler is minor because of low quantity carbon mono-oxide present in flue gases.

Heat loss due to hydrogen and moisture in fuel

This loss is due two inherent factors, hydrogen and moisture content of the fuel, which are beyond the control of boiler operators. The external factor, on which it depends, is the flue gas temperature, which can be controlled. This loss for package boiler #2 and #3 is calculated to be 7.16% and 6.82%, in the present condition. The annual saving of approximately Rs. 5,600 and Rs. 750 can be achieved in the package boiler #2 and #3 by reducing this loss to 6.74% as given in the **annexure 3.3**.

Heat loss due to moisture in air

This loss is because of moisture content in air which depends on the ambient dry and wet bulb temperatures. The other controllable factors on which this loss depends, are excess air level and flue gas temperature. By reducing the excess air level up to 20% and flue gas temperature to 160°C in package boiler #2 and #3, this loss can be brought down by 0.36% and 0.5% respectively. The annual saving for the boiler #2 and #3 on this account would be 0.42 T (or 0.5 KL) of LDO or Rs 7,500 and 0.21 T (or 0.25 KL) of LDO or Rs 4000 as calculated in **annexure 2.4**.

Heat loss due to blowdown

Presently, no scientific method is followed for checking blowdown TDS in the boilers and it is carried out twelve times everyday. It is necessary to blowdown boilers regularly in order to remove of precipitated salts, and to maintain water conditions as laid down by the supplier. Normally the allowable TDS for a fire tube type boiler is 3500 parts per-million (ppm). However, in the present case for boiler#2 and #3, TDS of blowdown was found to be 300, which is much below the recommended limit. Low TDS lead to the loss of boiler water (leading to higher loss of treated water, heat and higher feed water consumption). The TDS of blowdown should also not exceed 3500 ppm. For this purpose it is recommended to the management to procure a pen type TDS meter and check the TDS level before carrying out the blowdown. The investment in this regard will be Rs 8000 but it would lead to significant energy savings. The annual saving of approximately Rs. 0.38 lacs in boiler #2 and Rs. 0.25 lacs for boiler#3 could be achieved as calculated in **annexure 2.2 and 2.3** respectively. The payback would be about 1year and 2 months. The address of supplier of flue gas analyser and per type TDS meter is given below.

Techmark Engineers & consultants
56-D, D.D.A. Flats, Masjid Moth, Phase II,
New Delhi - 110 048
Fax: 011-6217979/ Tel: 6236974
E-mail: techmark@bol.net.in

Heat loss due to convection and radiation (structure)

The outer surface temperature indicates the level of insulation existing on the boiler. The structural loss from package boiler #2 and #3 is estimated to be about 1.0%. It is suggested to maintain this loss between 1-2%. The heat loss (based on average surface temperature) due to convection and radiation in small boiler is within the acceptable limit.

Recommendations

1. It is recommended to operate the boiler at the maximum level of designed pressure and quantity of steam.
2. It is recommended to supply the optimum combustion air to the boilers by adjusting the damper of FD fan and fine tuning the burner.
3. For the purpose of optimisation of excess air and TDS of blowdown water, it is recommended to the management to procure the portable oxygen analyzer and pen type TDS meter to check the oxygen in flue gas and TDS level (before carrying out the blowdown). The investment for the gas analyser and TDS meter will be Rs. 1.0 lacs and Rs 8000 respectively, but it would lead to significant energy savings. The annual saving of approximately Rs. 0.96 lacs and Rs. 1.67 lacs in the package boiler #2 and #3 could be achieved as calculated in **annexure 2.2**. The overall payback period would be about 4 months. The address of supplier of flue gas analyser and per type TDS meter is given below.

Techmark Engineers & consultants
56-D, D.D.A. Flats, Masjid Moth, Phase II,
New Delhi - 110 048
Fax: 011-6217979/ Tel: 6236974
E-mail: techmark@bol.net.in

Steam handling system & mode

Steam from boiler house is supplied through the main header to different lines of the breads/ loaves production in the plant. Steam boilers are connected with the header. Steam from any HRS and package/ small boiler is utilised directly in the final prover for adding heat and moisture. The pressure of steam generated from package boilers is different and adequate. Plant personnel reported that the adequate moisture is added occasionally by supplying steam of high pressure from one of the package boilers. Steam at a lower pressure from one of the HRS systems compels to switch-on the other system with high steam pressure. Feed water is stored in one common tank and directly sent to selective equipment for steam generation.

Reliability and safety review of tiny/small boiler in comparision to package boiler

In the existing small boiler, steam of minor quantity, low pressure is generated with large quantity smoke around it. Its steady operation required long time to raise the pressure of steam. The amount of smoke generation has been reduced with HSD firing in the small boiler. The firing of HSD should be allowed only to produce minimum smoke, stable flame, heat and provide almost smokeless working environment. Atmospheric air entry (along the circumference) for combustion should be restricted, guarded to achieve better flame and maximum heat utilisation. Steam between 1.5-2.5 kg/cm^2 (g) is supplied through mains to the oven.

Plant personnel have asked for general information (features on combustion, flame with stability and without back fire chance, safety, etc.) and components to be adopted with the locally designed tiny/ small boiler to make it like existing compact/ package boilers. It is suggested to consult the document on Indian Boiler Regulation, before installing selective component, to adopt practices, to achieve reliable and safe operation and performance of small boiler.

3

Baking ovens, final provers and tunnel coolers

The are three ovens in three lines for drying, baking breads/ loaves of different variety operating in the unit, which operate as per requirement. The average installed capacity of each of the three lines is 40000 Sl (standard loaf) per day (Sl/ day), which is equivalent to 1666.7 Sl/hr (667 kg/hr). The average moisture content in the breads/ loaves is reduced in the drying process. The oven No. 1 in line I, No. 2 in line II and No. 3 in line III is used for drying and baking breads/ loaves. The changeover is done from one product to the other after thorough changing of bread/ loaf carrying tin containers and cleaning of the processing line. During the energy audit, the oven No. 3 in line III was not in operating condition. Each oven is equipped with one baking section. Normally, two ovens operate for 24 hours daily. The annual (total of 12 months) operating hours of the oven No. 1, No. 2 and No. 3 for the period March 2001 – February 2002 was 6196 hours, 5408 hours and 5178 hours respectively. The total operating hours of the oven No. 4 for the period March – August 2001 (6 months) was 644 hours.

LDO is used as the fuel in the ovens. The baking section of each oven is fitted with one BENTONE burner and operates at preset firing rate with two nozzles of the burner. Two nozzles of each burner are of high pressure, efficient type is installed almost at the rear end of the oven. The actual fuel consumption at particular load on individual burner at different ovens is different. The actual consumption through individual nozzle of burner changes with load on the oven also. The fuel consumption of individual burner at the operating load of oven No. 1 and No. 2 was monitored. Plant personnel reported the following data on fuel consumption in ovens:

No. 1 (on April 15, 2002)	-	33 L/ hr,
No. 2 (on April16, 17 & May 1, 2002)	-	24 L/ hr, 23 L/ hr and 15.4 L/ hr

Cold air from atmosphere is drawn at the primary and secondary stage of the individual burner using the forced draught (FD) fan installed at the burner side in the oven. Each burner has 2-stage operation with which there is a reduced firing rate during start-up to minimise the sudden rise in combustion chamber pressure caused by the initiation of combustion. This low firing rate is of short duration and has little effect on the overall thermal efficiency of ovens. There is a provision of inspecting flame through the inspection door fitted with the individual oven. The generated flue gases are passed through the heat recovery system (HRS) and discharged to atmosphere through chimney located at the opposite side of burner in the individual oven. The moisture reduction takes place continuously at baking section of individual oven. The steam in minor quantity is generated at the individual baking section. It is partially, continuously discharged with breads/ loaves and through chimney. The flue gases at high temperature is circulated (drawn through the tapping before exit to atmosphere) from the rear side to the burner by the re-circulating fan. Normally, the flue gases is not circulated during summer season. It is continuously circulated through the individual final prover in other seasons and returned to chimney, at a point between HRS and flue gases tapping. There is no on line oxygen analyser in any of the three ovens, which can indicate the level of combustion. There is a provision of generating steam by the out going hot flue gases at the individual oven. There is no steam flowmeter installed with the HRS. Each HRS is provided with one panel to monitor the temperature of feed water, coil water, steam and flue gases at inlet/ outlet. Plant personnel reported about the wide pressure fluctuation of steam generated from HRS. The baking section of individual oven is also equipped with two online temperature indicator. There is a damper installed between the extraction and return point of flue gases at chimney of the individual oven. The damper in individual chimney was manually controlled and used to regulate flow of flue gases in the duct portion housing HRS (within chimney). Normally, the damper in 75% close condition helps to hold the gases and allows more heat availability for better generation of steam.

Month-wise production data for the period March 2001 – February 2002 was taken from logbook to estimate the average mass of breads/ loaves through the ovens. The average breads/ loaves mass through oven No 1 and No 2 were estimated to be 483.4 kg/ hr and 480.2 kg/ hr respectively. The average breads/ loaves mass through oven No 1 on April 15, 2002, was also estimated to be 752 kg/ hr. Plant personnel reported the mass of empty tin, mass of tin plus dough, mass of tin plus breads/ loaves before/ after oven No. 1/ No.2, standard quantity of maida and water in different type of dough. Plant personnel could not provide the breads/ loaves production of oven No. 2 on the day (April16, 2002) of measurement. Oven utilization or loading has enormous effect on breads/loaves production to fuel ratio. The oven-wise parameter/ data was measured/ collected is given below.

- Oxygen percentage in flue gases
- Carbon monoxide (CO) in flue gases
- Flue gas temperature
- Combustion air temperature
- Ambient condition
- Fuel consumption
- Surface temperatures
- Average temperature of baking section
- Temperature of breads/ loaves, tin at outlet and inlet of oven
- Average mass of tin through oven
- Average mass of dough at inlet and breads/ loaves at outlet of oven

The sample of flue gases was collected from a point on individual chimney after the hot gas is drawn for re-circulation and its return in two ovens. The sample of flue gases was also collected through the hole on the inspection door in oven No. 2. The existing insulation at the top and side (left, right, front and rear) on ovens are fully covered using mineral wool of 6 inches (152 mm) thickness and covered with the MS plate. The effectiveness of existing insulation was checked on all surfaces during the energy audit. In order to assess the heat loss due to radiation and convection, the surface temperatures were measured using a portable non-contact type temperature indicator. The information on specific spots of higher temperature level on different surface of two ovens is enclosed in **annexure 3.1**. The sum of useful heat (heat taken by breads/ loaves plus heat retained with moisture in breads/ loaves) and the unaccounted heat loss (=100 - total heat loss) has been computed. The arithmetical average of 12 months logbook data on fuel consumption, production of oven No. 1, No. 2 has been considered for the calculation of annual savings in quantitative unit (kL) and monetary unit (Rs.). The arithmetical average (of 12 months) fuel consumption of individual oven 26.3 L/ hr. The monitored fuel consumption has been used with the average level operating parameter (instantaneously monitored 2-3 sets) to compute the heat distribution. The operating information on different sets of parameter (level) at different time, location of two ovens is enclosed in **annexure 3.2**. The annual fuel savings estimation has been done considering various parameters on ovens. The parameters reported by plant personnel are given in the following sections.

No.1:
LDO consumption 33 L/ hr, mass of breads/ loaves 1880 Sl/ hr (or 752 kg/ hr, average production of April 15, 2002);

No. 2
LDO consumption 23 L/ hr, mass of breads/ loaves 480.2 kg/ hr (average production based on the month-wise logbook data on production asnd operating hours.

Oven (1) in Line I

The average of twelve months production of oven 1 for the period March 2001 – February 2002 was 1208 Sl/ hour. The production of April 15 (24 hours) in oven 1 was reported to be 1880 Sl/ hour, which corresponds to about 752 kg/ hour breads/ loaves. The production variety, the moisture removed and retained in baking was maida breads/ loaves (600 grams in 3 packets), 4.4% and 10.7% respectively. The percentage of moisture reduced throughout the baking time. The average weight of one empty tin at entry/ exit of oven was estimated to be 2.676 kg. The average temperature of tin at outlet of oven is 200°C. The average time of baking breads/ loaves of 600 grams is within 30-31 minutes.

The burner is installed at almost extreme end of the length of the oven. The average fuel consumption, for 12 months period is 26.3 lit/hr for the combined production of variety breads/ loaves. The primary and secondary air for combustion is adjusted with the manually operated proportionate controller as per fuel firing rate. The fuel pressure with the burner is maintained up to 7 kg/ cm^2 (g). The damper on chimney is manually controlled. It was found that most of time the damper at inlet was in about 40% open condition. The average temperature of flue gases was measured to be 308°C. The oxygen content in flue gases around baking section was measured to be about 9.95%. The MS cover plate on existing insulation is painted with white colour.

During the energy audit, all the operating parameters and surface temperature of oven 1 could be measured. The parameters were taken for the continuos operating condition and production of 600 grams breads/ loaves only. Since, the oven is performing similar operation for other breads/ loaves variety, therefore, heat balance of the oven with one product will represent other product also. The day-wise operating parameter in the oven 1 recorded by the team are enclosed in **annexure 3.2.** The average level of operating parameter is given in table 3.1.

Table 3.1 Average level operating parameter of oven 1

Sl. No.	Parameter	Avg. level
1	LDO consumption (litres/hr)	33.0
2	Oxygen in flue gas (%)	9.95
3	Carbon dioxide in flue gas (%)	8.2
4	Carbon monoxide in flue gas (%)	0.074
5	Temperature of flue gas (° C)	308
6	Moisture removed (kg/hr)*	34.9
7	Moisture retained (kg/hr)*	83.9

* estimated amount of moisture based on the production of April 15, 2002.

The temperature of all surfaces of the structure was measured to be in the range 55.0-74.3°C. The salient temperature of the LH side front segment and rear end surface of the oven is 74.3°C and 72.5°C respectively. The temperature is above the acceptable limit. The following sections discuss the methodology adopted for evaluating the oven performance, various measurements taken, and associated losses.

Heat balance of oven 1

The heat loss due to high excess air, high flue gas temperature, moisture in air and H_2 & moisture in fuel, radiation and convection through structure has been computed for different sets measurement. The average level of operating parameters has been considered for the calculation of overall heat losses and the heat balance. The percentage of various parameter of heat distribution/ losses associated with the oven 1 is calculated and the unaccounted heat losses is determined as the difference of 100 and the sum of the percentage heat distribution/ losses associated with oven. In the following sections, unaccounted losses and various heat distribution/ losses are evaluated based on the data collected and measurements taken at different time of baking, is given. The moisture content in breads/ loaves (before and after baking sections) has been considered for the overall estimation of the heat loss in moisture removal and heat retained in the moisture at exit.

Heat input

The average consumption (firing rate) of fuel (LDO) for the burner was monitored to be 33.0 lit/hr. The actual production based on the actual report of

April 15 and twelve months logbook data is 752 kg/ hr and 483.4 kg/ hr respectively. The corresponding loading on oven is about 112.7% and 72.5% of installed capacity. Thee average gross calorific value of LDO is 10200 kcal/kg. The total heat input to the oven is arrived at by multiplying the total fuel consumption rate with the gross calorific value of the fuel.

Heat distribution/ losses

As a part of the evaluation of parameter of heat distribution/ losses, a detailed heat balance was carried out which is enclosed in **annexure 3.2**. The analysis of flue gases sample was done during the HRS in closed condition, and analysing the gases through the chimney. The summary of the results of the heat balance as evaluated, is given in table 3.2.

Table 3.2 Heat balance of oven 1

S. No.	Type of heat distribution/ loss (in %)	Average level
1	Dry flue gas loss	18.01
2	Heat loss due to CO	1.17
3	Heat loss due to H_2 + moisture in fuel	7.49
4	Heat loss due to moisture in air	0.77
5	Heat (avg.) loss in moisture removal	8.19
6	Heat (avg.) retained in moisture	7.77
7	Heat taken by tin	8.31
8	Heat taken by breads/ loaves	40.07
	Structural heat loss	8.19
	Total heat loss/ distributed	99.97
	Unaccounted heat loss*	0.03

* include negligible heat loss to the moving band and bottom.

The heat balance shown above indicate 99.97% of the heat input is actually distributed and rest 0.03% is unaccounted heat loss. The various major heat losses in the oven 1 and ways to reduce them are discussed below.

Dry flue gas loss

The average dry flue gases loss in oven 1 is calculated to be 18.01%. The dry flue gas loss depends directly on the percentage of excess air and flue gas exit temperature. These two factors, if taken care of, can reduce this loss substantially. These are discussed below.

Excess Air Level

The quantity of excess air at about 112.7% loading condition, during the energy study, was found to be around 90%, which is on higher side. The higher excess air not only takes useful heat with it but also cools the oven. It is **recommended** to operate combustion with the existing burner at 40-50% of excess air level, which is the achievable standard to avoid overcome the backfiring for such oven fitted with re-circulating fan. This corresponds to oxygen content of 6.52% in the flue gases. Ideally, for oil firing an excess air level of 20-30% or oxygen level 3.5-4.8% is necessary to ensure the complete combustion takes place. The temperature of flue gases would also be substantially higher because of the excess air optimisation. It would also provide the opportunity of maximum steam generation using HRS. It is **also recommended** to replace the existing burner with 2 nozzles (without fine tuning provision over combustion air controlled level) by the efficient burner with 3 nozzles, which have very low level of excess air control system. The new efficient 3 nozzles burner develops the fuel spray and air flow pattern to achieve both complete mixing and stable flame pattern while requiring less overall excess air than existing 2 nozzles burner. In 3 nozzles burner the oil pump has an integral oil pressure-regulating valve, which can be adjusted to provide the necessary atomising pressure (between 7-14 kg/cm^2, g) to three nozzles of burner. The in-built intermediate solenoid oil valve and spray nozzle are provided with three nozzles to make smooth transition from low- to high- fire by balancing the fuel input with the increasing flow of air through the opening air damper, and is called staging. Maximum fuel input to the burner is achieved when all three nozzles are firing, assuming proper oil pressure is maintained by the fuel delivery system.

The average dry flue gas loss will come down by 4.3% at 45% excess air. Because of this the anticipated savings would be 14.26 T (or 16.8 kL) per annum of LDO or Rs. 2.50 lac per annum (based on anticipated annual production 7487442 Sloves in oven 1). Major/ significant savings could be achieved by the proper adjustment and its maintenance through out the year. Prior to that the simultaneous reduction in damper (manually operated) opening, O_2 in flue gases about 7% could be manually done and maintained for few months, which should not require any investment. The detailed calculation is given in **annexure-3.3**.

Flue gas exit temperature

The flue gases temperature was measured to be 308°C, when HRS is in close condition. The sample collection hole/ point was after the flue gases drawing and returning point involved for re-circulation. The temperature was on higher side particularly during the non-operating condition of HRS. Sometime, the large amount of soot within chimney would be diverting hot flue gases and discharging (after HRS) flue gases at higher temperature through the chimney. The minor increase (about 35-40°C) in flue gases temperature above the desirable level may be due to soot deposition inside the flue gases ducts and outside the water coil in chimney because of long run, which reduces the heat transfer to the moving air, breads, water and heat loss from flue gases. It is, therefore, suggested to get the ducts, coils cleaned during the oven shut down, in order to avail the benefit of lower flue gas temperature. It is also suggested to clean soot periodically and operate the HRS regularly at the highest efficiency level. It is expected that the flue gases temperature, during firing (with oven and HRS on line), will also get reduced after cleaning heat transfer surfaces and operating HRS by 35-40°C and up to 160°C respectively.

The existing drying oven 1 is operating at a low thermal efficiency. The average flue gas loss is 18.01%. The combustion should be optimised to reduce total heat loss at both conditions: (a) with HRS (b) without HRS. The flue gases over lower and upper portion of HR system helical coil could be thoroughly cooled by heat discharging/ absorbing to water, which will reduce (including temperature optimisation) flue gases loss in oven. The temperature fall of flue gases at first and second stage of HRS is the key parameter to achieve the optimum heat loss in the oven. It is recommended to replace the present MS coil by Stainless steel secondary coil in HRS, because the specific heat of stainless steel is about 5% less than that of MS. The approximate fuel savings after soot cleaning, coil replacing installing on line O_2 analyzer and HRS operating with (reducing flue gas temperature up to 160°C) the oven has been estimated to be about 11.7%. Because of this the savings would be 20.36 T (or 23.96 kL) per annum of LDO or Rs. 3.57 lac per annum (based on anticipated annual production 7487442 Sloves in oven 1). The detailed calculation is given in **annexure-3.3**.

It is **recommended** to calibrate the temperature indicators periodically thus avoiding any chance of over or lower heating/ baking of breads/ loaves. It is also recommended that the plant personnel may to contact the supplier of the instrument for calibration and stainless steel coil.

Loss due to Hydrogen and moisture in fuel

This loss depends on the hydrogen, moisture content of the fuel and flue gas exit temperature. The hydrogen, moisture content of LDO is constant and, therefore, the only controlling factor is the exit flue gas temperature. The average loss due to hydrogen and moisture in fuel is worked out to be 7.49%. However, this average loss will get reduced by 0.7% because of lowering in flue gas exit temperature by cleaning of ducts, coils and recovering heat. The savings, in this regard, would be around 2.3 T (or 2.7 kL) of LDO or Rs. 0.4 lacs per annum (based on anticipated annual production 7487442 Sloves in oven 1) as calculated in **annexure-3.4**.

Loss due to Moisture in air

This loss is because of moisture content in air, which depends on the relative humidity and the ambient temperature. The other controllable factors on which this loss depends, are excess air level and flue gas temperature. Presently, the average heat loss due to moisture in air is calculated to be 0.77%. By reducing the excess air level and exit flue gas temperature at each section, this average loss will be reduced by 0.53%. The savings in this account would be around 1.91 T (or 2.24 kL) of LDO or Rs. 0.33 lacs per annum (based on anticipated annual production 7487442 Sloves in oven 1) as calculated in **annexure-3.5**.

It is **also recommended** that the management may procure either one on-line O_2 analyser or a portable oxygen analyser to make a regular practice to check O_2 percentage in the flue gasses, at least once in every shift or whenever batch of breads/ loaves baking in the oven is changed. The investment and simple payback period for the on-line O_2 analyser would be about Rs. 6.0 lacs and 11 months respectively. The address of the flue gas analyser supplier is given below.

(1) Instrument: On-line and portable flue gas analyser

(i) M/s Techmark Engineers & Consultants
K1/28, Ground Floor,
Chittaranjan Park ,

New Delhi - 110 019
Phone: 011-6236974,6438349/6216003
Fax: 011-6217979,6236974
Email: techmark@bol.net.in

(ii) M/s Nevco Engineers Pvt. Ltd.
90 A, (II floor), Amritpuri B,
Main Road,
East of Kailash (Opp. ISKON Temple)
New Delhi - 110 065
Phone: 011-6226328
Fax: 011-6849247

Heat loss in moisture removal from breads/ loaves

This loss is because the heat is required to remove moisture from the breads/ loaves. The average quantity of moisture removed from the breads/ loaves during baking is about 34.9 kg/ hr. The average heat loss to remove the moisture is 8.19% of the total heat input to the oven.

Heat retained in moisture with breads/ loaves

This loss is because the heat is retained by moisture with the breads/ loaves after the complete baking. The average quantity of moisture retained with the breads/ loaves during baking is about 83.9 kg/ hr.The average heat retained by moisture is 7.77% of the total heat input to the oven.

Heat retained in tin (carrying breads/ loaves)

This loss is because the heat is retained by tin (carrying breads/ loaves) after passing through the entire oven. The average heat retained by tin is 8.31% of the total heat input to the oven.

Following is the possible method for reasonable reduction of this loss. Replace the existing container of tin with flat surfaces by tin with perforated surfaces. The diameter of each hole for perforation would be about 1-1.5 mm.

Heat loss due to convection and radiation

Prolonged usage of oven could also have resulted in deterioration at selective portion of the insulating materials, like mineral wool, paints on side plates, etc. on the side and top surface. This would also lead to the lower hot air temperature because of high heat transfer between hot air and atmosphere. The temperature of aluminium sheet covered bottom surface of the baking duct is within the acceptable limit. Table 3.3 shows the selective surface temperatures and the corresponding radiative and convective heat loss from the oven 1. The heat loss due to convection and radiation is evaluated using the average surface temperatures.

Table3.3 Heat loss from selective surface of oven no. 1

Location	Area (m^2)	Avg. surf. temp. (^0C)	Total heat loss (kcal/hr)
LHS front segment	8.5	74.3	1906
RHS front segment	71.0	71.0	1812
Top	67.0	67.0	3136

The structural heat loss is calculated to be 8.19%, which is high. Following measures and repair activities are the **recommended** for implementation for the structural loss improvement during shut down, in order to avail the benefit of higher hot air temperature.

1. Replace the damaged mineral wool insulation of the upper front segment of (LH & RH) side and top with the ceramic board of 2 inches inside and remaining mineral wool 100 mm outside,
2. Replace the white paint on hot surface (outside) of oven by aluminium paint,
3. Insulate the small patches of bare flat surfaces.
4. Procure the portable laser torch type temperature indicator to check the surface temperature of ovens (while in operating condition).

The investment for the portable temperature indicator will be about Rs.25000/-, but it would help for extensive measurement of surface temperature on the ovens, locate the high temperature spots and estimate the energy savings. The significant annual saving in the ovens could be achieved. The address of the portable temperature indicator suppliers is given below. The investment required for replacing (achievable saving about 35%, Rs. 0.89 lakhs) the selective damaged insulation surfaces on upper front segment of (LH & RH) side and top with one layer ceramic board (bulk density 128 kg/m^3) inside and mineral wool (bulk density 120 kg/m^3) of 100 mm thickness would be Rs. 6250, which will be paid back in about 1 month.

Instrument: Infrared Thermometer

1. Supplier - M/s. Puja Engineering,
107, Surat Sadan,
88/89 Surat Street,
Mumbai : 400 009.
Phone: 022-3780676 / 3735427
E-mail : "instrument@vsnl.net"
Fax : 022-5228013

2. Principal - M/s Airflow Development Limited,
U. K.

Indian supplier - M/s Techmark Engineers & Consultants
K1/28, Ground Floor,
Chittaranjan Park ,
New Delhi - 110 019
Phone: 011-6236974, 6438349
Fax: 011-6217979,6236974
Email: techmark@bol.net.in

Oven (2) in Line II

The average of twelve months production of oven 2 for the period March 2001 – February 2002 was 1201 Sl/ hour, which corresponds to about 480.2 kg/ hour breads/ loaves. The production variety, the moisture removed and retained in baking was maida breads/ loaves (400 grams in 3 packets), 14.5% and 0.2% respectively. The percentage of moisture reduced throughout the baking time. The average weight of one empty tin at entry/ exit of oven was estimated to be 2.614 kg. The average temperature of tin at outlet of oven is 195°C. The average time of baking breads/ loaves of 400 grams is within 28-29 minutes.

The burner is installed at almost extreme end of the length of the oven. The average fuel consumption, for 12 months period is 26.3 lit/hr for the combined production of variety breads/ loaves. The primary and secondary air for combustion is adjusted with the manually operated proportionate controller as per fuel firing rate. The fuel pressure with the burner is maintained up to 7 kg/ cm^2 (g). The damper on chimney is manually controlled. It was found that most of time the damper at inlet was in about 45% open condition. The average temperature of flue gases was measured to be 189°C after HRS. The oxygen content in flue gases around baking section was measured to be about 14.9% and it was reduced to 7.5% at the first stage adjustment.

The damper opening at inlet was manually changed and asked the plant personnel to maintain the reduced level of O_2 in flue gases and excess air. The O_2 in flue gases was reduced to 7.5% without much change in flue gases temperature. The MS cover plate on existing insulation is painted with white colour.

During the energy audit, all the operating parameters and surface temperature of oven 2 could be measured. The parameters were taken for the continuos operating condition and production of 400 grams breads/ loaves only. Since, the oven is performing similar operation for other breads/ loaves variety, therefore, heat balance of the oven with one product will represent other product also. The day-wise operating parameter in the oven 2 recorded by the team are enclosed in **annexure 3.3**. The average level of operating parameter is given in table 3.4.

Table 3.4 Average level operating parameter of oven 2

Sl. No.	Parameter	Avg. level
1	LDO consumption (litres/hr)	23.0
2	Oxygen in flue gas, after 1st reduction (%)	7.50
3	Carbon dioxide in flue gas (%)	10.0
4	Carbon monoxide in flue gas (%)	0.025
5	Temperature of flue gas (° C)	189
6	Moisture removed (kg/hr)*	81.4
7	Moisture retained (kg/hr)*	1.2

* estimated amount of moisture based on the production of April 16, 2002.

The temperature of all surfaces of the structure was measured to be in the range 44.0-77.8°C. The salient temperature of the LH and RH side front segment & rear end surface of the oven is 74.3°C & 72.7°C, 71.0°C and 77.8°C respectively. The temperature is above the acceptable limit. The following sections discuss the methodology adopted for evaluating the oven performance, various measurements taken, and associated losses.

Heat balance of oven 2

The heat loss due to high excess air, high flue gas temperature, moisture in air and H_2 & moisture in fuel, radiation and convection through structure has been computed for different sets measurement. The average level of operating parameters has been considered for the calculation of overall heat losses and the heat balance. The percentage of various parameter of heat distribution/ losses associated with the oven 2 is calculated and the unaccounted heat losses is determined as the difference of 100 and the sum of the percentage heat distribution/ losses associated with oven. In the following sections, unaccounted losses and various heat distribution/ losses are evaluated based on the data collected and measurements taken at different time of baking, is given. The moisture content in breads/ loaves (before and after baking sections) has been considered for the overall estimation of the heat loss in moisture removal and heat retained in the moisture at exit.

Heat input

The average consumption (firing rate) of fuel (LDO) for the burner was monitored to be 23.0 lit/hr. The actual production based on the twelve months logbook data is 480.2 kg/ hr. The corresponding loading on oven is about 72.0% of installed capacity. Thee average gross calorific value of LDO is 10200 kcal/kg. The total heat input to the oven is arrived at by multiplying the total fuel consumption rate with the gross calorific value of the fuel.

Heat distribution/ losses

As a part of the evaluation of parameter of heat distribution/ losses, a detailed heat balance was carried out which is enclosed in **annexure 3.2**. The analysis of flue gases sample was done during the HRS in operating condition, and analysing the gases through the chimney. The summary of the results of the heat balance as evaluated, is given in table 3.5.

Table 3.5 Heat balance of oven 2

S. No.	Type of heat distribution/ loss (in %)	Average level
1	Dry flue gas loss	8.33
2	Heat loss due to CO	0.40
3	Heat loss due to H_2 + moisture in fuel	6.88
4	Heat loss due to moisture in air	0.31
5	Heat (avg.) loss in moisture removal	27.1

6	Heat (avg.) retained in moisture	0.15
7	Heat taken by tin	8.4
8	Heat taken by breads/ loaves	28.39
	Structural heat loss	16.23
	Total heat loss/ distributed	**96.2**
	Unaccounted heat loss*	**3.8**

* include negligible heat loss to the moving band and bottom.

The heat balance shown above indicate 96.2% of the heat input is actually distributed and rest 3.8% is unaccounted heat loss. The various major heat losses in the oven 2 and ways to reduce them are discussed below.

Dry flue gas loss

The average dry flue gases loss is reduced after O_2 reduction at first stage from 14.98% to 8.33%. The corresponding quantity of excess air in oven 2 was reduced from 244.3% to 55.6%. Presently the average excess air is 55.6%, which is also high. The higher heat loss is mainly because of higher excess air. It is **recommended** to optimise the excess air, which would also substantially increase the flue gases temperature. The average temperature of exit flue gases is 160°C. The low temperature in the flue gases may be due to air in leakage from outside through joints of burner assembly part and loose fittings, which reduces the temperatures of flue gases. The exit gas temperature should be as low as possible but above the acid dew point of flue gases. If however, the temperature drops below the dew point, sulphuric acid will condense out and cause corrosion of metal or other oven flue material. Chimney expense is particularly undesirable due to the high replacement expense. From standard tables, a temperature of 160°C at the base of the chimney gives an exit temperature of 138°C. In order to prevent condensation of sulphuric acid the exit gas temperature should be kept at least 10°C above the dew point or 150°C. If excess air is not optimised in the present case, however, it may lead to sulphuric acid formation after cleaning tube and hence chimney corrosion.

The existing drying oven 2 is also operating at a low thermal efficiency after excess air reduction at first stage. Due to the high excess air, a good quantity of heat is wasted in to the atmosphere. The excess air quantity should be reduced further by manual adjustment to 40-50% to reduce total heat loss, which will reduce (including 10°C temperature reduction) flue gas loss by 0.56%. The additional heating of water in stainless steel helical coil is one of the parameters to achieve the minimum flue gases exit temperature and optimum heat loss in the oven. It is **recommended** to install one on-line O_2 analyser and replace the 2 nozzles burner by the new efficient 3 nozzles burner in the oven 2. The fuel savings after installing new efficient 3 nozzles burner and retrofitting (flue gas temperature reduce to 160°C including soot cleaning) the oven will be maximum corresponding to the estimated O_2 in flue gases up to 4.8%, which is the practical standard to overcome the backfiring for such oven fitted with re-circulating fan. The savings achievement because of the first stage manual adjustment and reduction (up to 7.5% oxygen level in flue gases) of excess air could be anticipated around 29.68 T (or 34.92 kL) of LDO or Rs. 5.2 lacs per annum (Rs.96 per hour, based on anticipated annual production 6492855 Sloves in oven 2).

The savings because of the second stage adjustment and reduction (up to optimum level) of excess air (without using new efficient burner) and flue gas temperature (soot cleaning) would be around 1.80 T (or 2.12 kL) and 4.49 T (or 5.29 kL) of LDO or Rs. 0.32 lacs and Rs. 0.78 lacs per annum (based on anticipated annual production 6492855 Sloves in oven 2). The detailed calculation is given in **annexure-3.3**.

The investment and payback for the on-line O_2 analyser would be about Rs. 6.0 lacs and 11 months respectively. The investment required for the new burner with 3 nozzles would be moderate, which would be paid back in few months on account of major, long-term savings in LDO. The fuel saving has been reported by the burner supplier to be 5%. The firm quotation of 3 nozzles burner is yet to be obtained. The payback period will be worked out for the installation of new burner, based on the indicative cost figure provided by the supplier. It is also recommended to contact the manufacturers for the total cost of new burner.

Loss due to Hydrogen and moisture in fuel

This loss depends on the hydrogen, moisture content of the fuel and flue gas exit temperature. The hydrogen, moisture content of LDO is constant and, therefore, the only controlling factor is the exit flue gas temperature. The average loss due to hydrogen and moisture in fuel is worked out to be 6.88% after first adjustment. However, this average loss will get reduced by 0.14% because of lowering in flue gas exit temperature by cleaning of ducts and helical coils after second adjustment. The savings, in this regard, would be around 0.45 T (or 0.53 kL) of LDO or Rs. 0.78 lacs per annum (based on anticipated annual production 6492855 Sloves in oven 2) as calculated in **annexure-3.4**.

Loss due to Moisture in air

This loss is because of moisture content in air, which depends on the relative humidity and the ambient temperature. The other controllable factors on which this loss depends, are excess air level and flue gas temperature. The average heat loss is reduced after O_2 reduction at first stage from 0.69% to 0.31%. Presently, the average heat loss due to moisture in air is calculated to be 0.31%. By reducing the excess air level and exit flue gas temperature, this average loss will be reduced by 0.07%. The savings achievement because of the first stage manual adjustment and reduction (up to 7.5% oxygen level in flue gases) of excess air could be anticipated around 1.51 T (or 1.77 kL) of LDO or Rs.0.26 lacs per annum (based on anticipated annual production 6492855 Sloves in oven 2).

The savings in this account because of the second stage manual adjustment and reduction (up to optimum level using on-line O_2 analyzer) of excess air (without using new efficient burner) and flue gas temperature (soot cleaning) would be around 0.23 T (or 0.27 kL) of LDO or Rs. 0.04 lacs per annum (based on anticipated annual production 6492855 Sloves in oven 2). The detailed calculation is given in **annexure-3.5.**

Heat loss in moisture removal from breads/ loaves

This loss is because the heat is required to remove moisture from the breads/ loaves. The average quantity of moisture removed from the breads/ loaves during baking is about 81.4 kg/ hr. The average heat loss to remove the moisture is 27.1% of the total heat input to the oven.

Heat retained in moisture with breads/ loaves

This loss is because the heat is retained by moisture with the breads/ loaves after the complete baking. The average quantity of moisture retained with the breads/ loaves during baking is about 1.2 kg/ hr. The average heat retained by moisture is 0.15% of the total heat input to the oven.

Heat retained in tin (carrying breads/ loaves)

This loss is because the heat is retained by tin (carrying breads/ loaves) after passing through the entire oven. The average heat retained by tin is 8.40% of the total heat input to the oven. Replace the existing container of tin with flat surfaces by tin with perforated surfaces.

Heat loss due to convection and radiation

Prolonged usage of oven could also have resulted in deterioration at selective portion of the insulating materials, like mineral wool, paints on side plates, etc. on the side and top surface. This would also lead to the lower hot air temperature because of high heat transfer between hot air and atmosphere. The temperature of aluminium sheet covered bottom surface of the baking duct is within the acceptable limit. Table 3.6 shows the selective surface temperatures and the corresponding radiative and convective heat loss from the oven 2. The heat loss due to convection and radiation is evaluated using the average surface temperatures.

Table 3.6 Heat loss from selective surface of oven no.2

Location	Area (m^2)	Avg. surf. temp. (°C)	Total heat loss (kcal/hr)
LHS front segment	8.5	73.4	1919
LHS rear segment	7.8	72.7	1622
RHS front segment	8.5	71.0	1802
RHS rear segment	7.8	77.8	1838

The structural heat loss is calculated to be 16.23%, which is very high. Following measures and repair activities are the **recommended** for implementation for the structural loss improvement during shut down, in order to avail the benefit of higher hot air temperature.

1. Replace the damaged mineral wool insulation of the LHS front & rear segment and RHS front & rear segment with the ceramic board of 2 inches inside and remaining mineral wool 100 mm outside,
2. Insulate the small patches of bare flat surfaces,
3. Install air curtain (above the rectangular opening for breads/ loaves entry and exit) to prevent radiative heat loss.

The significant annual saving in the ovens could be achieved. The investment required for replacing (achievable saving about 35%, Rs. 0.99 lakhs) the selective damaged insulation surfaces on upper front segment of (LH & RH) front and rear segment with one layer ceramic board (bulk density 128 kg/m^3) inside and mineral wool (bulk density 120 kg/m^3) of 100 mm thickness would be Rs. 5900, which will be paid back in about 1 month.

Heat recovery systems (HRS) for ovens

The heat recovery system (HRS) was installed as retrofitting for long term measure with the individual oven in the plant. The HRS was installed with the capability to replace/ totally discontinue use of the package/ small boiler in all seasons. The HRS was designed locally as per the recommendation of IIT, Delhi. The HRS was designed for continuous full load operation of the individual oven. In sizing HRS to the individual oven, it was necessary to consider actual volume of fuel used in oven under average and maximum conditions. Normally, if the HRS is reasonably small, early failure of the unit is expected; conversely, if the unit is sized reasonably large, poor heat transfer will result. The features such as inlet flow restrictors, large diameter tubes and other hydrodynamic factors had been thoroughly considered for the successful design and stable operation of HRS. The water flow rate of forced circulation is usually 5-10 times the maximum steam generating rate of the boiler.

The helical type primary and secondary coil is placed one above the other at the opposite side of burner in each oven. Each HRS is provided with one panel to monitor the temperature of feed water, coil water, steam and flue gases at inlet/ outlet. The actual temperature of flue gases before/ after the HRS in oven 2 was measured to be 315/ 189°C. The actual temperature (average) of flue gases before/ after the HRS in ovens is reported to be 290/ 180°C. The parameter of flue gases of oven considered for the design of HRS and its technical specifications are given in table 3.7 and 3.8 respectively.

Table 3.7: Designed parameter of flue gases of ovens

Sl. No.	*Parameter*	*Level*
1.	Flue gases quantity at full load	323 kg/hr
2.	Flue gases temperature at HRS coil inlet & full load	280°C
3.	Flue gases temperature at HRS coil outlet & full load	140°C

Table 3.8: Specifications of HRS

Sl. No.	Parameter	Working steam pressure (bar)		
		10	5	2
1.	Capacity at full load, kg/hr	17.4	17.6	17.9
2.	Saturation temperature, °C	179.9	151.86	120.23
3.	Feed water temperature, °C	25	25	25
4.	Feed water pump, litres/ hr	500	500	500
5.	Height of the HRS, mm			
	- primary section	880	880	880
	- secondary section	1430	1430	1430
6.	Diameter (ID/OD) of HRS	256/ 340	256/ 340	256/ 340
7.	Materials of the HRS coil			
	- primary section	SS 304	SS 304	SS 304
	- secondary section	MS	MS	MS
8.	PCD of coils, mm	220	220	220
9.	Location of damper on chimney	Between 2 coils	Between 2 coils	Between 2 coils
10	LDO consumption, kg/ hr	17	17	17
11	Heating surface area, m^2	2.85	2.85	2.85

Plant personnel reported about recent installation of feed water pump of 30 litres/ hr capacity for forced circulation. The temperature of steam from HRS has increased reasonably after that. The pressure fluctuation of steam generated from HRS has reduced after that from wide to normal level. The earlier installed pump was of 500 litres/ hr capacity. The provision of periodic soot cleaning of external surface of the tubes and chemically cleaning of two coils is to be adopted shortly in the plant. The manually controlled damper in chimney has been installed to maximise the steam generation. The flue gases flow to the HRS primary and secondary coil is not continuously controlled with the changing situation required in the damper/valve. It is reported that the damper/valve function on chimney at fixed level of setting. The operating control circuit of HRS is as follows:

- To switch-off the pump manually and shut off water supply to HRS when burner is OFF mode;
- To switch-on the manually and release water supply to HRS when burner is ON mode;

The conventional package boilers are working in case of HRS failure/ inefficient operation. During the study, it was found that the HRS with oven 2 was generating steam between 97-100°C temperature. The steam pressure was estimated to be in the range of 2.5-3.5 kg/cm^2 (g). The corresponding steam generation was not available, because there is no steam flowmeter installed with HRS. The possible steam generation in the HRS of oven 1 and 2 was estimated and given in the table 3.9. The HRS with oven 1 was not operating and energy at high temperature flue gases was not recovering. The maximum steam generation from the HRS would allow us not to avail the same quantity of steam from the package/ small boilers. The generated steam is not adequately available in prover , when major quantity of condensate is formed in hot pipes.

Table 3.9: Parameter for heat recovery systems

Sl. no	Parameter	HRS1	HRS2
1	Total amount of energy in flue gases, kcal/hr	51620 *	16653
2	Output (heat in steam) from HRS (50% conversion)**, kcal/hr	25810	8327
3	App. steam generated pressure, kg/cm^2, g	3.5	3.5
4	Enthalpy of steam at 4.5 kg/cm^2. Abs, kcal/kg	652.4	652.4
5	Quantity of steam generated, kg/hr	39	13

* Loading in oven was 12.7% more than the designed level.

** Based on the discussion with M/s Thermax Ltd.

The faster control operation of damper is recommended using pneumatic controls. It is recommended to install solenoid valve for automatically switching OFF & ON with burner for water supply to HRS, steam flowmeter, pressure gauge and contact the supplier of HRS for its overhauling. The fuel saving should be monitored in presence of the HRS supplier. It is also recommended to operate the HRS with the oven at optimum load condition and maximise the annual operating hours of the oven.

Final prover (FP)before oven

There are three final provers installed with three ovens for preheating breads/ loaves. The prover and oven is of the same average installed capacity (Standard sloves per day). The average of twelve months production of line 1, 2 and 3 for the period March 2001 – February 2002 was 1208 Sl/ hour, 1201 Sl/ hour and 1196 Sl/ hour respectively. The final prover before individual oven is used for humidifying and preheating the different variety doughs up to the desired level only. In the existing system design, entire quantity of steam at 2.45 kg/cm^2 (35 psi) pressure from the HRS/ boiler is allowed to disperse to add moisture and heat (above rectangular placed pipes passing hot flue gases) which is used to assist in rising the temperature of the dough (within prover). Sometime, the small boiler has been also operating to compensate the situation to maintain/ add adequate moisture and heat in final prover. Presently, the steam is sprayed/ purged horizontally in two directions using one tee-valve at the bottom. The doughs at corner start depriving of moisture during final proof in prover. The quantity of hot flue gases circulated through the recirculating fan and rectangular pipes is about 70%. The addition of moisture and heat indirectly transferred takes place during the movement of breads/ loaves. The residence time of each bread/ loaf is about 55 minutes. Plant personnel reported that the designed level of humidity in prover (after adding moisture in breads/ loaves) is about 90%. Hot doughs from the final prover are transferred manually to the oven.

During the study, the temperature of hot dough after prover in production line 1 and 2 was measured to be about 36.2°C and 37°C respectively. The actual humidity was recorded 56% and 73% from the humidity meter fitted with prover 1 and 2 respectively. The installed temperature indicator in prover 1 and 2 was reading about 40°C and 41°C respectively. The pressure, utilisation of steam inside individual final prover has been reported to be inadequate based on the observation on product. Plant personnel reported that the intermittently loading and non-uniform moisture distributing final prover systems would require better spraying of moisture supply. The spraying/ injecting system should be capable to throw moisture at desired pressure when doughs are inside. During the study, it was found that the steam pressure in the small boiler is between 1.5-2.5 kg/ cm^2 (g). The system performance of steam generating and distributing/ purging (for uniformly adding moisture and temperature) will have to be improved immediately.

The moisture added during final proofing in production line 1 and 2 was of reasonable quantity. The average temperature of surfaces was measured to slightly above the acceptable limit. The existing insulation inside the prover surface is of mineral wool and covered with the stainless plate.

During the energy audit, all the operating parameters and surface temperature could be measured in prover 1 ans 2. The operating parameters of the two provers recorded by the team are given in table 3.10.

Table 3.10 Operating parameter of final provers

Sl. No.	Parameter	Prover 1	Prover 2
1	Total energy input (kcal/hr)*	108120	93250
2	Humidity level (%)	56	73
3	Temperature of bread/ tin at inlet (° C)	34.3	34.3
4	Avg. tin temperature at outlet (° C)	36.2	37.0
5	Bread proof temperature (° C)	40	41

* estimated only.

The following sections discuss the methodology adopted for evaluating the oven performance, various measurements taken, and associated losses.

Heat balance of final provers

The percentage of various parameter of heat distribution/ losses associated with two provers is calculated and the efficiency plus unaccounted heat losses is determined as the difference of 100 and the sum of the percentage heat distribution/ losses associated with prover. In the following sections, unaccounted losses and various heat distribution/ losses are evaluated based on the data collected and measurements taken, is given. The weight, temperature of breads/ loaves in tins (before and after proof) is considered for the overall estimation of the heat loss with retained moisture and tin at exit.

Heat input

The average energy input through flue gases and steam in the prover 1 and 2 is 108120 kcal/ hr and 93250 kcal/ hr respectively. The heat input to the prover is considered by assuming 65% heat transfer through coil at base and the average steam consumption at about 3.5 kg/ cm^2 (g).

Heat distribution/ losses

As a part of the evaluation of parameter of heat distribution/ losses, a detailed heat balance was carried out which is enclosed in **annexure 3.6**. The summary of the results of the heat balance as evaluated, is given in table 3.11.

Table 3.11 Heat balance of final provers

S. No.	Type of heat distribution/ loss (in %)	Prover 1	Prover 2
1	Heat (avg.) retained in moisture	0.89	0.66
2	Heat taken by breads/ loaves	2.64	2.58
3	Heat taken by tins	0.26	0.31
4	Heat loss due to condensation	0.224	0.283
5	Structural heat loss	3.5	7.07
6	**Efficiency + Unaccounted heat loss***	92.49	89.1

- include significant heat loss to the frame, selective pipe with rust heat loss to bottom, and heat loss to moving air through openings at front, bottom.

The heat balance shown above indicate 92.5%, 89.1% of the heat input is accounted for thermal efficiency plus unaccounted heat loss and actual heat distributed is 7.51%, 10.9% for prover 1 and 2 respectively. The various heat losses in the provers and ways to reduce major loss are discussed below.

Heat retained in moisture with breads/ loaves

This loss is because the heat is retained by moisture with the breads/ loaves after the complete proofing. The average heat retained by moisture in prover 1 and 2 is 0.89% and 0.66% of the total heat input.

Heat retained in tin (carrying breads/ loaves)

This loss is because the heat is retained by tin (carrying breads/ loaves) after passing through the entire prover. The average heat retained by tin in prover 1 and 2 is 0.26% and 0.31% of the total heat input.

Heat loss due to convection and radiation

During the energy audit, the condition and quality of the insulation at selective patch/ surface was found to be deteriorating. Major portions of the base frame, selective pipes and bottom were bare. Selective pipeline was also bare.

With a view to assess the effectiveness of existing insulation on hot surface, measurements of surface temperature were taken using a portable non-contact type temperature meter. The average temperature of surface is slightly above the acceptable limit. Table 3.12 shows the surface temperatures and the corresponding radiative and convective heat loss from the prover surfaces. It is evident from the measurements that the heat loss from the damaged insulated surfaces is significant.

Table 3.12. Heat loss from selective surface of provers

Location	Area (m^2)		Surf. temp. (^oC)		Total heat loss (kcal/hr)	
	Prover 1	Prover 2	Prover 1	Prover 2	Prover 1	Prover 2
Front end, flat	7.3	7.3	40	64	570	3148
LHS	27	27	41	40.2	1333	1175
RHS	27	27	41.3	41.75	1392	1481
Rear end, flat	10.5	10.5	36	39.8	251	791

The structural heat loss prover 1 and 2 is calculated to be 3.5% and 7.07% respectively. Following measures and repair activities are the **recommended** for implementation for the structural loss improvement during shut down, in order to avail the benefit of higher hot air temperature.

1. Replace the small patches of damaged insulation on the front end and, RHS in prover and RHS in prover,
2. Significant savings can be achieved by applying ceramic paint at the inner hot surface of provers.
3. Check the steam transporting hot pipes and replace the damaged section of pipes. The steam could be sprayed from the top (roof level of prover) through four shower type (cross like) outlets.

The investment required for applying paint would be reasonable. Normally, the investment is paid back in few months.

Cooling tunnel (CT)after oven

There are three cooling tunnels installed with three ovens for cooling warm breads/ loaves. The average installed capacity (Standard sloves per day) of cooling tunnel is compatible to the respective oven and final prover. The cooling tunnel after individual oven is used for retaining moisture and cooling the different variety baked breads/ loaves up to the desired level only. Out of 3 cooling tunnels, two were tested for analysis. The tested cooling tunnels were fitted with the aluminium fan blades. The tunnel is equipped with one manually operated forced draught fan, one induced draught fan and balanced draught circulation system. The air washers are also fitted with aluminium fan blades, vertically placed through which cold air passes to the duct. The detail of the cooling tunnels is given in the table 3.13. Two cooling tunnels were operating during the plant visit.

Table 3.13 Design detail of cooling tunnels

Sl. No.	Parameter	C. Tunnel 1	C. Tunnel 2	C. Tunnel 3
1	No. of CTs	1	1	1
2	Make	Baker Perkinson, Australia	Baker Perkinson, Australia	Baker Perkinson, Australia
3	Rated capacity (Sl/ hr)	1900	1900	1900
4	Design inlet temp. of bread (0C)	92-95	92-95	92-95
5	Design outlet temp. of bread (0C)	28-30	28-30	28-30
6	Designed humidity level inside cooler (%)	75	75	75
7	No. of trolleys inside cooler	8	8	8
8	Fan motor rating (hp)	3.0	–	3.0
9	Fan diameter (metres)	0.6	0.6	0.8
10	Rated capacity of fan (cfm)	4500	4500	N.A.

N.A. – Not available.

The annual operating days of each of the three cooling towers is 363. In the existing system design, the maximum number of trolleys with fully/ partially loaded breads/ loaves after packing is resided to dissipate heat and maintain moisture, which is used to assist in reducing the temperature of the hot breads/ loaves (within cooling tunnels). Normally, the entire space inside the tunnel is not fully filled with the hot breads/ loaves (in packet) on trolleys. The quantity of cold air with moisture above 75% humidity from the air washer is allowed to absorb heat of breads/ loaves and retain moisture. Presently, the cold air with moisture is sprayed horizontally in one direction using one fan at the breads/ loaves exit side. The breads/ loaves at right side periphery start retaining heat when hot air ingress through the partially open sliding doors and mix with cold air. The moisture quantity, circulation through the fan and leakage could be improved and stopped. The cooling and distribution of moisture takes place during the movement of breads/ loaves. The residence time of each bread/ loaf is about 85 minutes. Plant personnel reported that the designed level of humidity in tunnel (after supplying cold air and spraying moisture around packet of breads/ loaves) is about 75%. Warm and cold breads/ loaves across the cooling tunnels are handled manually.

During the study, the temperature of warm and cold breads/ loaves before and after cooler in production line 1/ 2 was measured to be about at about 89°C and 190°C respectively. The average humidity was recorded about 77% from the humidity meter fitted with tunnel cooler 1. The humidity meter fitted with cooler 2 was not working. The setting of installed temperature indicator in cooler 1 and 2 was between 27-28°C. The air flow, moisture inside individual cooler has been reported to be inadequately utilised based on the observation, information on product in batches. Plant personnel reported that the intermittently loading and adequate moisture adding cooling tunnel systems would require more efficient spraying of moisture and cold air supply. The spraying system is to be capable to throw moisture at desired temperature when warm breads/ loaves are inside. During the study, it was found that the loading in the cooler 1 and 2 is between 85-90%. The system performance of cold air supplying and moisture spraying will have to be improved.

The humidity maintained during cooling in production line 1 was of above the designed level. The moisture addition in air washer of cooler 2 should also be of adequate quantity. The average temperature of surfaces was measured to slightly below the acceptable limit. The outside surfaces of cooler are of MS and painted white.

During the energy audit, most of the operating parameters and surface temperature could be measured in cooler 1 and 2 respectively. The operating parameters of the cooler 1 recorded by the team are given in table 3.11.

Table 3.10. Operating parameter of cooler 1

Sl. No.	Parameter	Level
1	Energy input *	
	- fan motor rating (HP)	N.A
	- pump and fan motor rating in air worker (kW)	5.2
2	Avg. humidity level (%)	77
3	Temperature of breads/ loaves at inlet (° C)	89.0
4	Temperature of breads/ loaves at inlet (° C)	19.0
5	Avg. trolley temperature at inlet (° C)	34.3
6	Avg. trolley temperature at outlet (° C)	19.0
7	Set temperature of cooling (° C)	27.4

* Estimation and monitoring could not be done.

The following sections discuss the methodology could be adopted for evaluating the cooling tunnel performance, various measurements taken, and associated losses.

Heat balance of cooling tunnels

The percentage of various parameter of heat distribution/ gains associated with two coolers could be calculated and the unaccounted gains to be determined as the difference of the sum of the percentage heat distribution/ gains (plus) and the sum of the heat loss (minus) associated with tunnel. In the following sections, unaccounted gains and various heat gains and losses are evaluated based on the data collected and measurements taken, is given. The weight, temperature of breads/ loaves in trolleys (before and after cooling) was considered for the overall estimation of the heat dissipated (added to system) with warm breads/ loaves and trolleys. The heat addition contributed by warm breads/ loaves, trolleys and structural heat gain was estimated to be 25615 kcal/ hr, 119 kcal/ hr and 1533 kcal/ hr respectively. Total heat addition was 27267 kcal/ hr.

Heat distribution

The average energy/ heat (absorbed) extraction (kcal/ hr) through cold air and moisture in the cooler 1 was estimated, based on rated capacity of fan (or designed quantity of air circulated). The structural heat gain (in absolute term, corresponding to radiative and convective heat gain) has been computed, based average temperature of selective surfaces. The average load in cooling tunnel could be assumed about 90%. The summary of the results of the heat balance as evaluated, is given in table 3.11, which is enclosed in **annexure 3.7.**

Table 3.11 Heat balance of cooling tunnel 1

S. No.	Type of heat distribution/ gain	Level (in %)
1	Heat (avg.) retained by moisture	17.6
2	Heat absorbed by circulating air	66.5
	Total heat extracted (efficiency)	**84.1**
	Unaccounted heat extraction/ gain*	**15.9**

- include significant heat extraction/ gain by left side of tunnel and heat extraction/ gain by air ingress.

Energy savings

Reduction in heat addition (gain) through cold surfaces

Table 3.12 shows the selective surface temperatures and the corresponding heat gain to the cooler 1. The heat gain due to convection and radiation is evaluated using the average surface temperatures.

Table 3.12. Heat gain to selective surface of cooler 1

Location	Area (m^2)	Avg. surf. temp. (^oC)	Total heat gain (kcal/hr)
RHS			
Exit door	2.4	20	322
Fixed plate	4.8	26.8	256
Entry door	2.4	27.5	115
Rear end, flat	3.1	30	125
Top	9.7	28.5	716
Total			**1533**

The annual monetary loss due to structural heat gain is calculated to be about Rs. 17,000, which is significant. Following measures/ activities are the

recommended for implementation for the structural gain improvement during shut down, in order to avail the benefit of lower cold air temperature.

The inner sides, top of bare cold surface of tunnel coolers should be painted with low emissivity aluminium colour. Insulate (outside) the exit door, fixed plate and top of the tunnel by thermocol sheet. The operating time reduction in every shift for pumping water and simultaneous electricity savings can be achieved. The cold air entry to the tunnel should be prevented carefully. The investment required for applying paint and thermocol would be of minor amount.

Installation of FRP blades

By replacing the existing aluminium fan blades with hollow FRP in the cooling tunnel 1 a saving of 1352 kWh or Rs. 4600 per annum is possible with a payback period of around 2 years 7 months as calculated in the **annexure 3.8**. The address of the supplier is given in the cooling tower chapter.

Checklist of Oven & heat recovery system (HRS)

Sl	System/ Parameter
	Oven
1	Fuel consumed with shift-wise break-up (kg/day)
2	Fuel pressure, kg/cm^{2}g
3	Time of instantaneous measurement
4	Damper opening of FD fan (%)
5	Flue gases temp. from inspection door (°C)
6	Flue gas composition by volume from inspection door (%)
	CO_2
	O_2
	Any other
7	Flue gases temp. at chimney (°C)
	- before HRS (if working)
	- after HRS (if working)
8	Damper opening on chimney (%)
9	Flue gas composition by volume at chimney (%)
	Exact sampling point
	CO_2
	O_2
	Any other
10	Feed water temperature, °C
11	Coil water temperature, °C
12	Operating steam pressure, kg/cm^{2}g
12	Operating steam temperature, °C
14	Formation/ colour of smoke
	Recirculating Fan working/not working
15	Estimated quantity of steam Kg/hr.

4

Compressed air systems

There are four numbers of air compressors operating in the breads/ loaves producing unit. Three compressors under the asbestos shed are oil free reciprocating type compressors. Each of the three compressors is two stages and air cooled type. The number of compressors in running condition depends on the operation of breads/ loaves baking ovens. Normally, three compressors run to operate two production lines. Fourth compressor on the roof is not in working condition.

The compressed air is generated, stored without conditioning (removal of moisture and dirt) and supplied for the purpose of pneumatic operation in depanovac of three ovens through the individually in-built receiver and the common header. Each compressor is fitted with one horizontal type air receiver separately. Air receiver is fitted with manually operated drain valve to facilitate the water drainage. The operating pressure range at the receivers is 9.5-11.5 kg/ cm^2 (g). The compressors were provided with the arrangement of switching-on and off automatically as the lower and upper pressure limits are achieved. The automatic switching-on and -off arrangement fitted with compressor no. 1 and no. 3 was not working properly.

The model of three compressors is IR 253 and their other detail is given in Table 4.1. Each compressor is fitted with air suction filter and receiver separately.

Table 4.1. Detail of three air compressors & receivers

Sl. No.	Sl. no. of air receiver	Make	Year of installation	Motor (HP)	Rated pressure (kg/cm^2)	FAD (m^3/min)
1	3364	Ingersoll Rand	1968	7.5	12.95	34
2	N. A	Ingersoll Rand	N. A	10.0	12.95	34
3	AR 039	Ingersoll Rand	1995	7.5	12.95	34

Plant personnel reported that the intermittently operating depanovac systems would require further switching-on and –off in compressed air supply. Presently, the air is blown before the depanovac starts loosening the bread in baking tin. The proximity switch installed to control the air supply is not working sensitively as per the required sequence. The controlling system should be capable to blow compressed air at desired pressure when tins are on-line.

Free air delivery (FAD) test

Compressors are designed to deliver the fix quantity of air at certain pressure. But, due to ageing, wear and tear or poor maintenance compressor may not deliver the specified quantity of air. By performing this test, actual output of a compressor can be assessed. Performance of the four reciprocating compressor is given in table-4.2 below.

Table 4.2. Operating parameters of receiver and compressors

Sl. No	Parameter	Comp. #1	Comp.#2	Comp.#3
1	Capacity of the receiver (m^3)	0.304	0.308	0.217
2	Capacity of the interconnecting pipes (m^3)	0.002	0.002	0.002
3	Initial pressure (bar abs.)	1.013	1.013	1.013
4	Final pressure (bar abs.)	11.96	12.36	8.97
5	Avg. pump-up time (minutes)	5.883	6.212	3,681
6	Actual FAD (m^3/min)	0.559	0.555	0.463
7	Design FAD (m^3/min)	0.57	0.57	0.57
8	Average of actual load on motor (kW)	2.94	2.85	2.78
9	Sp. power consumption (kW/m^3/min)	5.26	5.14	6.00

If the actual free air delivery, by the above test, comes below 80%, of the rated or designed capacity, the compressor needs overhauling. It is clear from the table that actual FAD of compressor #1, #2 and #3 is 98.0%, 97.4% and 81.3% respectively. The FAD for compressor #1 and #2 is very good. The compressor #3 is delivering compressed air marginally above the satisfactory level (okay). Because of this, specific power consumption for compressor #3 is higher compared to other compressors. It is, therefore, recommended to ensure proper maintenance of three compressors to obtain actual FAD above 80%. The overhauling requirement of individual compressor should be attended immediately to achieve the better productivity and lower energy consumption.

Compressed air leakages

Compressed air leakage forms a major source of energy wastage. During the energy audit study, considerable leakage in the distribution system was noticed from pipe joints, valves, etc. The leakage test covered air distribution from compressor to lines up to depanovac of oven #1, #2 and #3. It is strongly recommended to identify the leakage points and arrest the same. Though, it is not possible to make compressed air system 100% leak proof, but air leakage above 10%, certainly, needs in-depth study of the network. The leakage test, to quantify the leakages in the distribution system was carried out three times, during the visit, when the operation of all the machines using compressed air had to be discontinued. During the first and second trial, the individual compressor did not unload for 3-4 hours because of the major leakage of compressed air in the distribution system. Selective number of leakage points was plugged before the third trial for overall leakage test.

The leakage in the compressed air system can be quantified by running the compressor with all air using equipment shut off. The leakage rate in the compressed air line before third trial was assessed to be very high. Major savings in electricity was achieved because of plugging off heavy leakage in the plant. The hourly basis monetary saving would be very high. It was suggested to operate 2 compressors with 2 production lines. The third trial of leakage test was carried out with the compressor #1. Three sets of reading were taken after plugging major leakage in the plant. The leakage rate in the compressed air line is calculated to be 40.5%. Even leaving a margin of 10% leakage for untraceable points in the compressed air line, the reduction in electricity consumption achievable in the unit, with plugging the leakage would be handsome amount annually. The annual electrical energy saving is 5016 kWh, and the corresponding monetary saving would be RS. 0.233 lacs. The details are given in annexure 4.1.

Detecting leakage points

It is difficult to detect air leakage as they can not be seen and smelt. While large leakages are easily detected by hissing sound generated, it is difficult to detect small leakages, which can only be detected by applying soap solution. Some of the most susceptible points are:

a) threaded pipe joints
b) flange connections

c) valve stems
d) traps and drains
e) filters
f) hoses
g) connectors
h) operating valves on pneumatic device
i) check valves
j) relief valves
k) end use machines or tools

Plant personnel reported that the selective number of major leakages were plugged within 1-2 days before third trial during our visit. Leakage detection test was carried out in the compressed air line of three ovens in the plant. Major loss of compressed air was observed during the first two trials. During third trial the compressor #1 was properly loading/ unloading and based on it minor leakage was estimated.

The air loss due to leakage can be quite significant depending on the air pressure. Table 4.3 gives the leakage through various orifice size and energy wastage at 7 kg/cm^2 (g) air pressure.

Table 4.3. Power wastage at 7 kg/cm^2(g)

Orifice dia.	Air leakage (scfm)	Power wasted (kW)
1/64"	0.406	0.08
1/32"	1.62	0.31
1/16"	6.49	1.26
1/8"	26	5.04
¼"	104	20.19

(m^3/min = 39.2 scfm)

Ensure proper closing of valves while the machines are not in operation. Plug the leakages immediately. It is recommended to maintain the compressed air distribution system properly and get the entire system tested with soap solution once in every six months. Following measures are also recommended to improve the performance of the compressed air system.

- Plug the air leakage. Most of the threaded joints in the pipes on ground/ overhead should be made leak proof by welding at the ends.
- Operate the compressors in the plant at full load condition.
- Replace old pipes for the compressed air distribution.

Inlet air temperature

The small sized air intake pipe and filter of the compressors is located within the compressor shed. Temperature of air in the ambient and compressor room was measured using thermocouple and it was found that the temperature of the inlet air to the compressor was higher than the ambient temperature. The actual temperature of suction (within shed) air for three compressors has been given in the table 4.4.

Table 4.4. Air temperature for suction (within shed) of compressors

Compressor no.	1	2	3
Ambient temp. (°C)	34.8	34.8	34.8
Suction air temp. (°C)	37.9	40.6	44.5
Difference (°C)	3.1	5.8	9.7

The actual temperature of suction air in compressor # 1, # 2 & # 3 is much above the ambient temperature. However, care should be taken against any increase in the suction air temperatures. The inlet temperature of air to the compressor is very important, as rise in temperature will increase the energy consumption because of increased volume of air. Thus, lesser the temperature of air at compressor inlet lesser would be the energy consumption of compressor. The effect of inlet air temperature on compressor performance is given in Table 4.5.

Table 4.5 Effect of inlet air temperature on compressor performance

S.No	Temperature of intake air (°C)	Volume required to deliver 1000 m^3 at 21°C (m)	Percentage saving/loss related to 21°C
1	5	943	5.7
2	10	982	3.8
3	16	981	1.9
4	21	1000	0
5	27	1020	-1.9
6	32	1040	-3.8
7	37	1060	-5.7
8	43	1080	-7.6
9	49	1100	-9.5

Note. The negative sign in the table indicates energy loss

Following measures are recommended for the performance improvement of the compressors.

1. Suction air to be maintained at the temperature close to ambient throughout the compressor operation in all seasons.
2. Relocate the air inlet (suction pipe with filter) to the compressor #3 out of the shed to allow the suction air (temperature and flow) as ambient. The reduction in electricity consumption is achievable immediately in the compressor.
3. Temperature of the air supplied to the suction of compressor #1, #2 and #3 should be monitored periodically to ensure that it is, at least, equal to the ambient temperature.

4. Install the new compressed air management system to reduce the wastage of compressed air at depanovac. The controlling system should be capable to blow compressed air when tins are on-line. The firm quotation is yet to be obtained from the following supplier.

   GODREJ & BOYCE MFG. CO. LTD.
   Electrical & Electronics Services Dept.
   Pirojshanagar, Vikhroli, Bombay: 400 079.
   Email: hnd@godrej.com / kcp@godrej.com.
   Tel: 022 – 5962251 to 55, Fax: 022 – 5961525

Use of automatic drain valve in air receiver

It was observed that the air receivers drain valve was manually operated to facilitate the water drainage. Moisture is drained from the receivers thrice a day. This provision not only passes the water but also allow the compressed air to pass to the atmosphere intermittently. By using the automatic drain valve, water would only be allowed to pass intermittently, thereby, reducing the wastage of compressed air. The addresses of the above drain valve suppliers are given below-

1. Trident Electric Pvt. Ltd.
   #133, I Floor, 11th Cross
   Opp. Jeerige Building
   Malleswaram,
   Bangalore-3

2. Siemag Hi-tech Filters Pvt. Ltd.
   #7, New Lata Apartments
   Jawahar Nagar, Goregaon(W)
   Bombay-40006

5

Cooling Towers

The plant is equipped with three numbers of cooling towers to meet the cooling water requirement of three air conditioning/ chilling units in the breads/ loaves producing plant. Out of 3 towers, two were tested for the performance analysis. The tested cooling towers were of single cell induced draft type. They are fitted with aluminium fan blades and identical PVC fills vertically placed through which water falls in to the sump. The detail of the cooling tower is given in the table 5.1. All the cooling towers were not operating during the plant visit.

Table 5.1. Design detail of cooling towers (CT)

Sl. No.	Parameter	CT 1 serving 15 TR AC (unit 1)	CT 1 serving 20 TR AC (unit 2)	CT 1 serving 40 TR AC (unit 3)
1	No. of CT's	1	1	1
2	Make	Delta	PECO	PECO
3	Motor rating (hp)	1.0	2.0	2.0
4	Fan diameter (inches)	24	24	30

The annual operating days of each of the three cooling towers is 300.

Performance Evaluation

The performance of two cooling towers was evaluated when the equipment were operating at normal load condition. The parameters measured were temperatures of incoming and out going cooling water, ambient dry and wet bulb temperatures, total dissolved solids, pH of water in cooling tower sink, etc.

The range (difference in cooling tower inlet and outlet water temperature) and approach (difference in cooling tower water outlet and ambient air wet bulb temperature) for these cooling towers are given in table 5.1 along with the measured parameters. Range and approach are two main factors governing the performance of a cooling tower. For optimum performance, range should be as high as possible and approach should be as low as possible.

Table 5.1. Performance of cooling towers (CTs)

Sl. No.	Parameters	CT 1	CT 3
1	Average in-coming water temperature to cooling tower (°C)	37.7	38.4
2	Average out-going water temperature from cooling tower (°C)	34.5	30.9
3	Dry bulb (ambient) temperature (°C)	37.0	37.0
4	Wet bulb (ambient) temperature (°C)	30.0	30.0
5	Range (°C)	3.2	7.5
6	Approach (°C)	4.5	0.9

The outgoing water temperature from cooling tower No. 3 is lowest. Due to this, approach is also lowest for this cooling tower. However, the outgoing water temperature in cooling tower No. 1 is far from the ambient wet bulb temperature and, therefore, has the highest approach. Likewise, range is also low because of higher temperature of outgoing water from No. 1 (going to unit 1).

Fills

The fills in a cooling tower facilitate heat and mass transfer between the circulating water and the air. All the cooling towers in the plant are having PVC fills. They were not performing properly, particularly in cooling tower No. 3. The temperature of water falling at the bottom of the fills (along the length of the basin) could be measured from the outside of the cover. The inadequate or non-uniform fall of temperature (range) of water (along the length of the basin) may be because of the partial clogging of fills and water not falling uniformly along the periphery of basin. It is recommended to inspect the section of fills periodically and replace the clogged/ jammed portion. It would provide maximum exposed surface area of water jet/ spray to air for better heat transfer.

Use of hollow FRP fan blades

The fan blades of cooling towers are made of aluminium. Nowadays, hollow FRP blades are available which can replace aluminium fan blades and contribute the energy savings. FRP blades being lighter in weight give higher efficiency. The higher efficiency is also due to the special aerodynamic design, streamline finish and lightweight of the blades. Also, the airflow rate through fans would improve by 5 to 10% and will yield energy saving of 15%.

By replacing the existing aluminium fan blades with hollow FRP in the cooling tower #1 and #3 a saving of 504 kWh and 1007 kWh or Rs. 0.023 lacs and Rs. 0.047 lacs per annum is possible with a payback period of around 3 years

10 month and 2 years 7 months as calculated in the Table A5.1 in Annexure 5.1. The payback period for the replacement of aluminium fan blades with hollow FRP of the cooling tower #3 is attractive. The address of the supplier is given below.

1. Cooling Tower Corporation,
   GIDC, Makarpura,
   Vadodara-390010

2. Melfrand Engineers Pvt. Ltd.
   17/18, Kamlesh Apartments,
   Sher-E-Punjab Andheri (E),
   Mumbai – 400 084
   Tel: 022-5118348/5106709
   Mobile: 9820106369
   Fax: 022-5167667
   E-mail: melfrank@bom3.vsnl.net.in

Installation of thermostatic controllers in No.1 cooling tower

The outgoing water temperature from the cooling tower No. 1 and No. 3 is 34.5°C and 30.9°C respectively. The designed setting of water temperature at inlet or outlet of the cooling tower #3 is not available. It is 35°C and 33°C at inlet or outlet of the cooling tower #1. It is suggested to switch off the cooling tower fan when the ambient temperature falls below the 22°C during the months of November (last half), December, January, February, March (first half) and night of April (first half), September and October. It is proposed to install the simple electronic single cell CT-ENSAVER+ system consisting of one micro-controller, two sensors. The temperature setting of controller with cooling tower No.1 should be adjusted at 22-24°C. This retrofit will switch off the fan as soon as the water (in cooling tower trough) temperature falls below 22°C (duration is specified above) and switch on the fan at 24°C automatically. It also indicates cumulative fan on and off-hours to estimate the excess capacity of the cooling tower. During the fan off condition, only free fall area of cooling tower will be utilised. It is recommended to install the CT-ENSAVER+ system (thermostatic controller) in the cooling tower No.1 and No.3. The month-wise reduction/ switched off (not running) hours of cooling tower no. 1 is given in the table A5.2. The savings in the cooling tower No.1 and No. 3 because of switching off the fan by about 3480 hours will be 1623 kWh and 3245 kWh or Rs.0.075 lacs per annum and 1.51 lacs per annum as given in the Table A5.3 in Annexure 5.2. The payback period for the installation of CT-ENSAVER+ system in cooling towers No.1 and No. 3 is 2 years 4 months and 1 year 2 months respectively. The address of the supplier is given below.

Ensave Systems Private Limited
3, Anand Shopping Center,
Second Floor, Bhattha, Paldi,
AHMEDABAD - 380 007
Phone : (079) 662-1116 / 661-4609
Fax : (079) 663-7907
E-mail : maxprotech@satyam.net.in

6

D G Sets

There are three D.G. (Diesel generating) sets in the plant. The rated capacity of each of the two identical sets is 250 kVA. It is 63 kVA for the third set. The D.G. sets have been installed primarily to substitute the grid power supply, which is erratic. Electricity from DVB is used to meet the regular plant's requirement. Generally, the D.G sets will be operating throughout all the months to supply power. Plant personnel reported that the average load on large D.G. sets varies between 70-80%; and the 63 kVA set is supplementing the power supply to one of the two sets. HSD is used as fuel in the D.G sets. DG set is equipped with a fuel day tank. There is no flow meter for the measurement of fuel to the D.G sets. During the time of energy audit, it was found for a few hours, two 250 kVA sets one after the other was under operation. Temperature of air in the ambient and D.G. sets room were measured using thermocouple and it was found that the temperature of the inlet air to the set was close to the ambient temperature. The design details of the D.G sets are given in table6.1.

Table 6.1 Design detail of the D.G sets

Parameter	Set 1 (250 KVA)	Set 2 (250 kVA)	Set 3 (63 kVA)
Make	Ruston & Homsby (I) Ltd.	Ruston & Homsby (I) Ltd.	Ruston & Homsby (I) Ltd.
Model	TBD232 V12	TBD232 V12	N.A.
AC Generator			
Capacity (kVA)	250	250	63
Voltage (V)	440	440	N.A.
Power factor	0.8	0.8	0.8

Operating characteristics of the D.G sets

The operating characteristics of 250 kVA D.G set were studied with regard to lube oil consumption and drain practices. The specific energy generation ratio (SEGR) could not be studied for either of the individual set of 250 kVA and 63 kVA. The measurements of energy related parameters were taken and the observations made are presented below. Based on the observations and the outcome of the simple calculation, some practical measures are suggested to improve the efficiency, thereby lowering the operating costs of D.G set.

Loading of D G Sets

Plant personnel could not report the designed specific energy generation ratio (SEGR in kWh/litre of HSD) of D.G sets at either full or part load operation. *SEGR of a D.G set is a performance indicator which is proportional to the extent of loading of the set.* At part load operation, the efficiency of the D.G set drops down with a consequent decrease in the SEGR value. The variation of SEGR value with the loading of a set is shown graphically in figure 6.1, which clearly demonstrate the above fact.

Figure 6.1

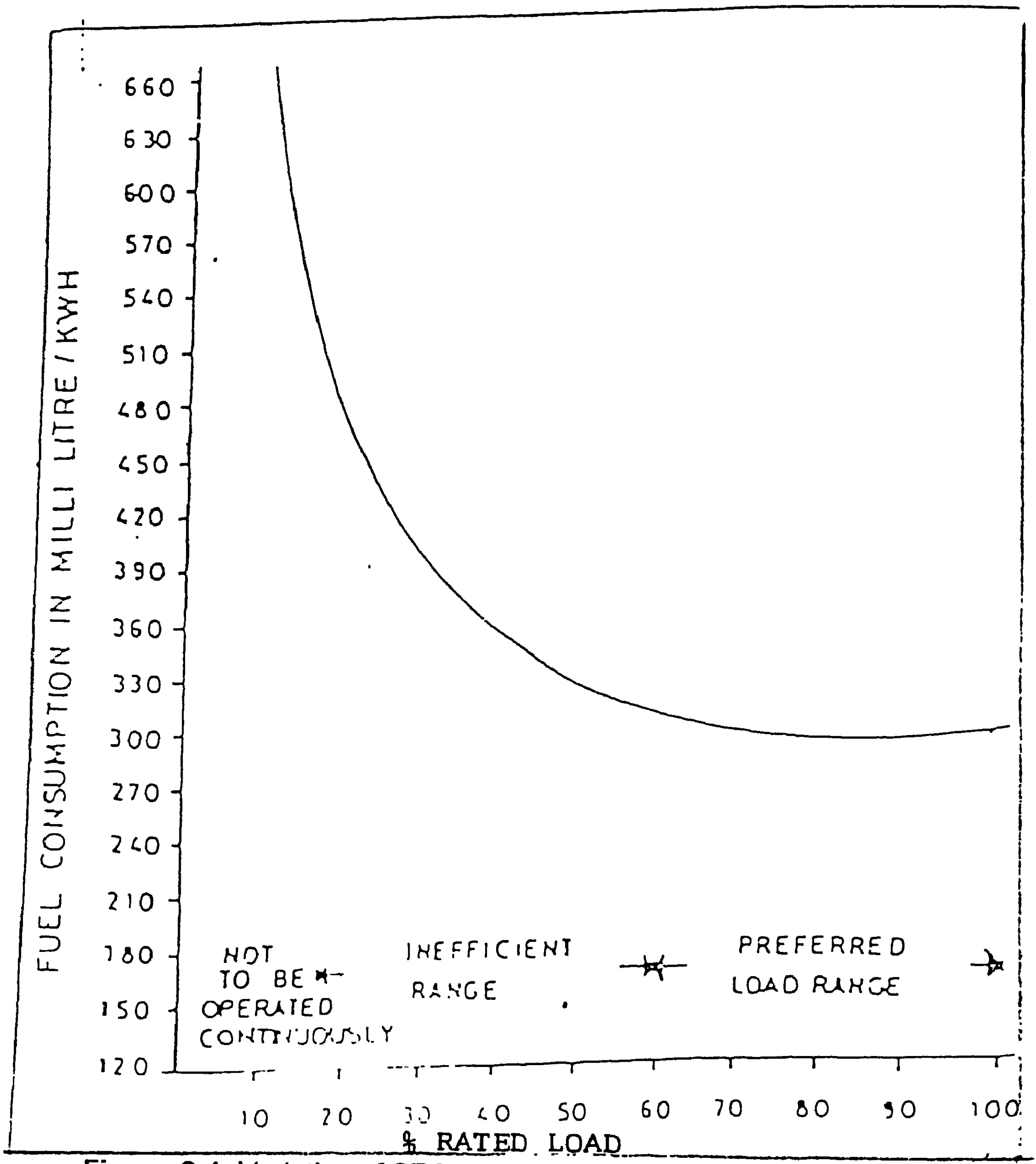

Figure 6.1 Variation of SEGR value with the loading of a set

Each of the two D.G sets (250 kVA) is in operation and the loading on the D.G sets varies from time to time, depending on the load and availability of grid power. Normally, both sets are loaded higher than 75 percent when there is no grid power avialable. The kWhs generated and operating time of the DG set 1 and 2 was measured. The average fuel consumption and kWhs generation of three sets is 6280 litres/ month and 16648 kWhs/ month based on the twelve months cumulative logbook data. The corresponding average SEGR of twelve months cumulative data is 2.65 kWh/ litre. The electricity generation and loading calculation for set 1 and 2 has been given in the table 6.2. Plant personnel reported the HSD consumption of about 40 litres/ hr and 90 litres/ hr respectively. The level change in the fuel tank was monitored using the dipstick arrangement. The SEGR of set 1 and 2 was computed to be 2.87 kWh/ litre and 1.02 kWh/ litre, which is very low. The cumulative SEGR of three sets using average fuel consumption of corresponding months (April and May 2001) has been computed, but it may not be representative level of SEGR for the individual set. Month-wise data on fuel consumption for the period April 2001 to March 2002 was available from the logbook. The actual loading on set and hours of operation for the same were not available.

Table 6.2. Operating data for D.G set 1 and 2

Set no.	*Duration (min)*	*Operating phase parameter*		*Generated (kVA)*	*Units generated (kWh)*	*Loading (%)*	*SEGR (kWh/l)*
		Voltage, V	*Current, Amps*				
#1	30	410	230	163	65	37.7	
	20	410	200	142	38	32.8	
	20	410	220	156	42	36.1	
	20	410	165	117	31	27.1	
	20	410	190	135	36	31.2	
	20	410	195	138	37	32.0	
Sum	130				249		
Sum, hrs	2.17						
In 1 hour					**115**		
	HSD consumption/ hr				**40**		**2.87**
#2	20	410	130	92	25	21.3	
	20	410	120	85	23	19.7	
	20	410	193	137	37	31.7	
	20	410	213	151	40	34.9	
	20	400	150	104	28	24.0	
	20	400	173	120	32	27.7	
Sum	120				184		
Sum, hrs	2.00				**92**		
In 1 hour					**90**		**1.02**

It was found that the cumulative average (of three sets) SEGR was about 2.65 kWh/ litre. It appears to be much lower than the recommended level (range for individual set) 3-4 kWh/l by any manufacturer of the DG sets.

The operating data (HSD consumption and power generation) of set 1 and 2 was monitored for 130 minutes and 120 minutes, because the generator set/ month-wise operating hour (for actual) data was not available in the logbook. The power generation was computed for some duration for set 1 and 2 respectively. The SEGR for set 1 and 2 was computed based on the reported HSD consumption of about 40 litres/ hour and 90 litres/hour respectively. The average SEGR of two months (corresponding duration involved during measurement in 2002) period (April and May 2001) data is about 2.95 kWh/ litre, which is also lower than recommended level. The actual HSD consumption (ltr/hr) of individual set could be neither recorded for operating months in logbook nor computed for the monitoring intervals by us. The cumulative electricity generation and HSD consumption for 12 months period (April 2001 – March 2002) calculated for three sets has been given in the table 6.3.

Table 6.3. Operating data from logbook for three DG sets (between April 2001-March 2002)

Month	HSD consumption (litres)	Electricity generated (kWh)	SEGR (kWh/ l)
Apr-01	3050	14320	4.70
May	13450	33520	2.49
June	6350	15000	2.36
July	8000	18960	2.37
Aug.	9720	23680	2.44
Sep.	7230	18640	2.58
Oct.	10550	26880	2.55
Nov.	2200	5440	2.47
Dec.	2400	6120	2.55
January 2002	6800	19240	2.83
February	2309	5830	2.52
March	3300	12150	3.68
Total	**75359**	**199780**	
Avg.	6280	16648	2.65

The cumulative figure of HSD consumption and power generation considers the operation of 365 days and three DG sets. The total generation of units and HSD consumption in 365 days (corresponding to 12 months) is 199780 kWh and 75359 litres respectively. The SEGR is calculated to be in the range 2.36-4.7 kWh/litre. The SEGR value based on the logbook data is well below the recommended level by any manufacturer, except for the period of March 2002 and April 2001.

The selective duration (20-30 minutes) basis load on two sets was computed, based on the operating voltage and current data. The loading on set 1 and 2 was monitored to be about 27.1-37.7% and 19.6-31.6%, which is very low. It is recommended to monitor and record the fuel consumption, kWhs generated, hours of operation and power factor for each of the D.G. sets in operation on daily basis. Using these data, the overall SEGR value for the individual generator set should be computed. This will enable the plant personnel to evaluate the efficiency of each set in operation on a regular basis. Its profile should show that the overall SEGR value of the individual generator set is satisfactory and close to the design level.

Irrespective of the number of D.G. sets in operation, it must be noted that the D.G. sets be loaded to the optimum level (80 percent). This will ensure the best operating condition of the D.G. sets.

Lubricating oil usage

The recommended grade for lubricating oil by the D.G set manufacturer is not available. However, in actual practice, the DELVAC Super 1300 15W/ 40 multi-grade oil having a viscosity of 20W-40 only. The initial lube oil charge to the sump is 75 L for each of the set 1 and 2 respectively. The lubricating oil is supposed to be drained after every 8 months of operation in the sets as per the manufacturers' recommendation.

The recommended oil drain level can be extended further without damaging the engine by "**condition-monitoring**" of the used lubricating oil. There are certain physico-chemical properties of lube oil which must be evaluated to assess the condition of the used oil. These properties are: (i) viscosity at 40°C and 100°C, (ii) total base number, (iii) water content, (iv) insoluble build-up. It is recommended to monitor the lube oil condition on a regular basis using a portable test kit which will help in extending the drain interval thus saving on valuable lube oil. However, as regard the check parameters, test procedures and the corresponding rejection limits, the D.G. set manufacturer has to be consulted. Facilities required to carry out these tests can be provided in-house and this cost around Rs. 30000. The cost of the monitoring system would be paid back from the savings due to longer engine oil drain periods resulting in reduced lube oil consumption.

Recommendation

The lube oil consumption must be monitored for individual D.G. set along with fuel consumption details. The ratio of lube oil to fuel consumption is indicative of mechanical efficiency of the engine. Generally, the recommended ratio of lube oil to fuel is 0.01.

Engine cooling system

The engine parts of the D.G. set 1 and 2 are radiator and water-cooled. It is equipped with sump type system.

Inlet air quality

The inlet temperature of air to the D.G. set is very important as rise in temperature will increase the energy consumption for compression because of increased volume of air. Thus, less the temperature of air at the inlet less would be the energy consumption for compression.

Recommendation

Care should be taken against any possible change in flow, and temperature of inlet air. Air at the inlet to be maintained at the temperature close to ambient throughout the D.G. set operation.

7

Demand management and power factor

7.1. Electricity distribution

M/s Modern Foods Limited receives power supply from DVB (Delhi Vidyut Board) at 11 kV. The power supply at 11 kV is stepped down to 433V through distribution transformers and fed to different load centers in the plant. Additionally, the plant has installed 3 DG sets (2 x 250 kVA , 1 x 63 kVA rating) as a back up to the existing DVB supply.

Tariff structure

The total connected load of the plant is 900 kW. The power billing from DVB is based on electricity consumption (kVAh) and contract demand during the billing period. The contract demand of the plant is 460 kVA. The plant has to pay a demand charge @ Rs 150 per kVA for the contract demand irrespective of actual maximum demand recorded in a month. The electricity is charged at the rate of Rs 3.40 per kVAh.

An analysis of the billing demand from March'2001 to March'2002 was done to assess the scope of reduction in contract demand. This is presented in table1 below.

Table 7.1. Billing Demand

S.No	Month	Maximum Demand (kVA)	Billed/contract Demand (kVA)
1	March'01	284	460
2	April'01	284	460
3	May'01	284	460
4	June'01	297	460
5	July'01	297	460
6	August'01	297	460
7	September'01	297	460
8	October'01	297	460
9	November'01	297	460
10	December'01	297	460
11	January'02	297	460
12	Februray'02	297	460
13	March'02	297	460

It could be seen from the table that maximum demand recorded in all the months is less than the billed (minimum payable/contract) demand i.e. 460 kVA, indicating the scope for reduction in the contract demand of the plant. Discussion with the plant personnel revealed that the contract demand is to be at least 60 % of the total connected load. At present the connected load of the plant is 900 kW and the lighting load contribute to the 50 % of the total connected load. The reason for high-connected load is large number of non-operating loads in the plant. It is recommended that possibility of reducing the connected load should be explored. It has been worked out that if the connected load of the plant is reduced to 500 kW, the contract demand can be fixed around 350 kVA. This will result in a saving of 110 kVA per month, which in monetary terms is Rs. 1.98 lacs per annum.

Transformer

There are three transformers installed, two of 500 kVA rating each and one of 200 kVA rating, to step down the incoming power supply at 11 kV to 0.415 kV. A total of 900 kW load consisting of AC motors and lighting has been connected to these transformers. Under normal operating condition, the complete load of the plant is kept on one 500 kVA transformer with other two transformers as standby. The standby 500 kVA transformer is kept completely de-energized whereas the primary of 200 kVA is kept energized.

Loading the transformers in excess or below the load for their maximum efficiency level would result in drop in operating efficiency of the transformers, consequently resulting in wastage of electrical energy. Since the peak load of the plant is 297 kVA (60% of its rated capacity), the entire load of the plant should be put on one 500 kVA transformer with other two transformers (500 kVA and 200 kVA) completely switched off. After sometime, say 15 days or one month, load should be shifted to standby 500 kVA transformer so that moisture level in the stand by transformer is with in acceptable range. This will result in a saving of no-load losses of 200 kVA transformer. The no-load loss of 200 kVA transformer was measured to be 1.1 kW. Therefore, by keeping the 200 kVA transformer completely switched off will translate into a saving of 9636 kWh per year (1.1 kWx24hoursx365days). This in monetary terms would be about Rs. 32,000/- per year. This scheme would not require any investment since no cabling arrangement is required to feed whole of the load from one transformer, thus resulting in immediate payback.

7.2. Power factor

The line current drawn by Induction motors, transformers and other inductive devices consists of two components; the magnetising current and the power producing current. The magnetising current is required to produce the magnetic flux in the machine. This component of current creates a reactive power compensation which is measured in kilo-volt amperes reactive (kVAR) The power producing current is that current which reacts with the magnetic flux to produce the output torque of the machine. This component of current creates the load power requirements measured in kilowatts (kW). The magnetising current and magnetic flux are relatively constant at constant voltage. However the power producing current is proportional to the load torque requirements. The magnetising current is essential for transferring power through the core of the transformer or across the air gap of an induction motor. The magnetising current lags the voltage by 90 degree. The total current drawn by the machine is the vector sum of this reactive current and the power producing current. The power factor is defined as the cosine of the angle between total current and power producing current vectors.

Low power factor leads to poor system efficiency as the high reactive component associated with low power factor gives rise to additional losses through out the system. An improvement in the power factor leads to

- Reduction of load on transformer and distribution equipment.
- Reduction of load losses in transformers, distribution cables and other equipment
- Resulting in a direct savings of kWh power consumption
- Stabilisation of the system voltage

Present power factor scenario

The average monthly power factor of the plant was noted down from the electricity bills starting from March 2001 to March 2002. Figure 1 shows the variation and trend of monthly power factor for the above period. It could be observed from the figure that monthly power factor of the plant varied from 0.94 to 0.98. It can also be observed from the figure that the plant has been able to maintain a consistent monthly power factor above 0.93 during March 2001-02.

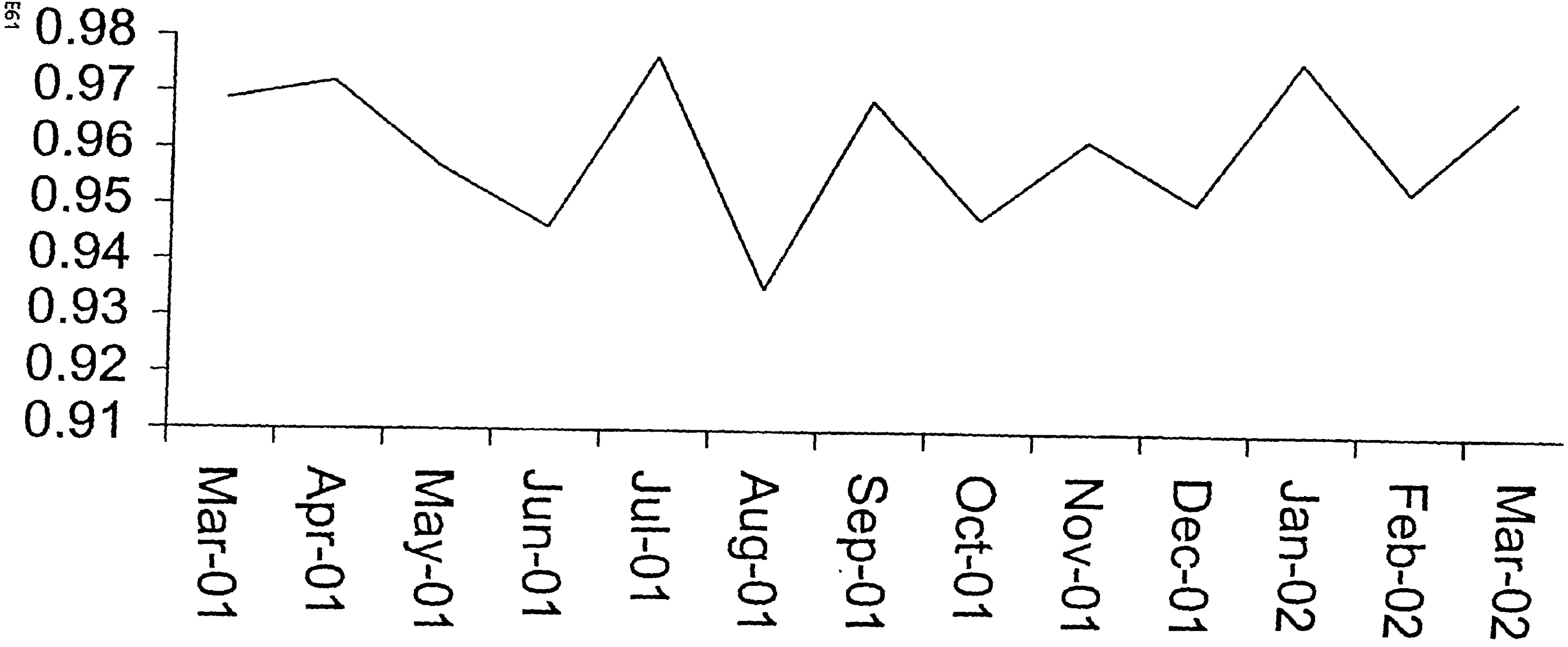

Figure 1:Monthly power factor variation

Existing compensation scheme

A total of 263 kVAR of capacitor banks has been installed in the plant for improving the power factor. The plant has a combination of centralised and individual compensation scheme where some of the banks are located on the main bus and some at individual motor terminals. Presently all installed banks are switched on manually.

Power factor measurements

Power factor measurements were carried out to evaluate the performance of the existing reactive power compensation scheme and suggest improvements.

Performance of the installed capacitor banks

The condition of all installed capacitor banks was checked to know the exact kVAR being supplied by these capacitors in the system. The measurements are presented in table 2. It should be noted here that the capacitor banks installed in the plant have been rated to supply at 415V. However, the measurement of actual kVAR supplied by these banks has been calculated at the actual voltage measured at that time.It can be observed from table that six out of eight banks were delivering kVAR more then 50% of their rated value. Two banks installed in plants 1 and 3 respectively were delivering kVAR less then 50% of their rated capacity. It can also be seen that at present 138.3 kVAR is being delivered to the system as against an installed capacity of 195 kVAR (tested) when all banks are switched on.

Table 7.2: Performance of installed capacitor banks (Operating voltage 398V)

Bank	Bank (kVAR)	Average current	KVAR	Performance
Bank 1(LT panel 1&2)	25	27	18.7	81%
Bank 2(LT panel 1&2)	25	31	21.7	94%
Bank 3(LT panel 3&4)	55	61	42.0	83%
Bank 4(LT panel 3&4)	40	47	32.3	88%
Plant2 capacitor bank	15	15	10.3	75%
Plant3 capacitor bank	15	8	5.2	38%
Plant1 capacitor bank	10	4	3.1	33%
Slicing section	10	7	5.0	54%
Total *	195		138.3	77%

*Tested

Analysis of the existing compensation system

1. At present the installed banks are delivering a total of 138.3kVAR.While the peak kVAR requirements for achieving a target power factor of 0.98 is about 170 kVAR (assuming initial PF= 0.7, kVA 297).
2. The wide variation of the average power factor could be attributed to manual switching of the capacitor banks and variation in the operating load of the plant.

Proposed Compensation Scheme

1. A centralised compensation scheme (where all banks are connected in the main bus) should be followed in the plant.
2. The installed banks should be connected through APFCR (Auto Power Factor Correction Relay). This type of relay operating in auto mode senses the load, voltage, and current of the connected system and automatically controls switching of capacitor banks to deliver the kVAR requirements (for a present PF value) at all loads. This would facilitate easy maintenance and the present operating practice of switching off bank when DG is operated could be done easily.

Techno economics of proposed scheme

By maintaining a power factor of 0.98 with the proposed scheme the plant can reduce its kVAh consumptions.The details of savings obtained for maintaining an monthly average power factor above 0.98 is given in table 3. The saving are calculated on the basis of electricity bills during the year (2001-2002). It is observed that an annual savings of about Rs 83497 is possible by improving the power factor to 0.98

Table. 7.3. Monetary savings from power factor improvement

Month	KWh	kVAh	PF	Improved kVAh	Reduction in kVAh	Saving in(Rs)
Mar-01	68808	71028	0.97	70212	816	2774
Apr-01	78636	80904	0.97	80241	663	2255
May-01	73128	76440	0.96	74620	1820	6187
Jun-01	114528	121068	0.95	116865	4203	14289
Jul-01	81060	83004	0.98	82714	290	985
Aug-01	103224	110388	0.94	105331	5057	17195
Sep-01	98676	101832	0.97	100690	1142	3883
Oct-01	93636	98792	0.95	95547	3245	11033
Nov-01	83760	87060	0.96	85469	1591	5408
Dec-01	84324	88668	0.95	86045	2623	8919
Jan-02	91224	93408	0.98	93086	322	1096
Feb-02	72048	75564	0.95	73518	2046	6955
Mar-02	71904	74112	0.97	73371	741	2518
Total savings						83497

The investment required for the proposed scheme would be about Rs.80000 this will be paid back in 0.96 years.

8

Electric motors

The energy audit of motors installed in the plant was carried out to study analyse and identify the potential for energy conservation in motors. The study included motors installed in the process as well as in utility section of the plant. The study focussed broadly on the following two aspects, which have bearing on energy use efficiency of motors.

- Loading of motors
- Energy saving options

The details of the measurements taken and observation made about each of the above two aspects are detailed in the following sections.

8.1. Motor loading

Selecting a motor with correct horse-power rating for an application is usually difficult because of several constraints as outlined below.

- Lack of information on torque-speed characteristics of machines
- Possible deterioration in machine conditions with improper maintenance
- Possible changes in production process parameters

A simple solution to deal with many of these uncertainties is to play safe and overdesign i.e. select a motor of higher rating. This can result in low shaft loading on motors resulting in power wastage apart from higher initial cost. Therefore in general improving the loading (for the same shaft load) of such motors can lead to improved operating efficiency and reduced electricity consumption. This can be done by replacing the existing motors by smaller rated motors. However there are several factors like type of application, speed torque characteristics of both load and motor, efficiency level etc. which effects the success of such replacements. Moreover, the replacements needs to be justified economically (simple payback around 2 to 3 years). Hence a detailed study is necessary to short list such motors.

To evaluate the performance of motors and to see how they are loaded, load tests were conducted on 9 motors. Care was taken to record the peak load on the motors to decide the extent of over or under loading . Table 1 gives the result of load test conducted on motors during the field study. It can be seen from this table that motor loading varied from a low of 39 % for -oven recirculation fan–1 and as high as 85 % for Mixer plant-1

Table.8.1: Motor loading *

Application	Rated		Measured			
	Rated(kW)	RPM	kW	V	I	loading
Mixer (plant-1)	18.5	1440	17.4	226	28	85%
Deponovac Unit-1	7.5	2800	5.37	226	9.44	59%
Deponovac Unit-2	7.5	2800	6.3	216	10.8	70%
Ovan recirculating fan-1	7.5	1440	3.63	236	7.79	39%
Ovan recirculating fan-2	3.7	1440	3.84	236	7.55	83%
Aircompressor-1	7.5	1440	3.93	226	7.47	43%
Air compressor-3	5.5	1440	3.99	218	7.57	59%
Chilling compressors (plant2)	15	1440	10.8	216	19.7	64%
Chilling compressors	15	1440	9.9	211	18.9	59%

* Corresponds to the load during the time of measurements. Efforts was taken to record the peak loads as far as possible.

To achieve the best design efficiency and power factor values, it is recommended that motor should be loaded in the range of 70-90 percent of the rated power. Possibilities of replacement with lower size motor in cases where the loading was less than 50% was studied. It was however found that techno-economics of replacement of these motors was not favorable (high pay back).

8.2.Other options

Transmission drives

Various methods have been used in the plant to transmit the motive power to the mechanical equipment. These methods range from simple direct coupling to V-belt coupling between motor and the load. An audit of various types of transmission drives in the plant has been carried out to identify the energy conservation opportunities in this area.

Classification of V-belt loading

It has been observed that in many conventional drive systems like fans, compressors, pumps, blowers etc., V-belts are being used for transmission of motive power. In all these cases, it would be possible to replace V-belts with modern flat belts, which result in 5-12 percent energy saving. This saving is possible due to certain inherent properties of modern flat belts and their operational characteristics, which are discussed in annexure 8.1. An energy saving potential has been worked out by use of modern flat belt in place of existing V-belts. Data for all the motors employing V-belts was collected to work out economics involved in replacement with flat belts. Since the details of some of the drives, which was not provided and in some cases it was not proper, these motors could not be analysed for such measure. The annual savings and payback period for these replacements are given in table 2. The annual energy saving have been calculated by assuming a very conservative estimate of 5% saving due to use of modern flat belts. It could be calculated from the above analysis that there would be a total annual saving of about Rs.18,000/- by adopting this measure with a total investment of Rs.20,000.

It is advisible that before carrying out the retrofitting of V- Belt with flat belt, a trial should be carried out at one particular drive in consultation with the suppliers. On being convinced, the subsequent drives can be taken up.

Table.8.2: Economics of flat belt retrofit

Application	Measured power (KW)	Savings (kwh)	Savings (Rs)	Investment (Rs) *	Payback (years)
Air compressor-1	3.93	1414.8	4810.32	5000	1.0
Air compressor-3	3.99	1436.4	4883.76	5000	1.0
Oven recirculating fan	3.63	1306.8	4443.12	5000	1.1
Oven recirculating fan	3.84	1382.4	4700.16	5000	1.1
Total savings			18837.36	20000	1.1

* Rough estimate quotation awaited.

9 Lighting

9.1. Introduction

Adequate and proper lighting contributes both directly and indirectly towards productivity and safety, and towards providing an improved work atmosphere. In fact, all these are inter-related and complimentary to each other. There are several factors which contribute towards proper lighting and it would be very difficult to deal with all of them when providing general illumination to a large area. However, all efforts were made to study and include these factors.

To study, analyze and identify energy conservation options in lighting, a study of the plant lighting load was conducted. This study included the lighting load in the plant as well as office areas. The purpose of the study was to determine the lighting load and its distribution in various sections of the plant, determine the quality of illumination provided, and recommend measures to improve illumination and/or reduce electricity consumption.

A high quality and accurate digital lux meter was used to measure the illumination level at several sections of the plant.

9.2. Lighting load

To determine the total lighting load, a physical count of the number of light fixtures provided in different sections of the plant as well as in the non-plant areas was carried out. It was found during the survey that mainly 40-W fluorescent tube light have been used in the plant as well as in the offices areas.

Based on the analysis of the data collected, the total installed lighting load of the plant works out to be about 32.6 kW (excluding ballast wattage) which forms about 5.4 per cent of the total connected load of about (605 kW) of the plant. This installed lighting load includes the lighting load of the main plant and offices. Table 1 gives the total lighting load by the type of lamp and table 2 gives the total lighting load of different areas in the plant. It could be seen from table 1 and table 2 that the Fluorescent tube lamps have found maximum use in the plant. While external lighting accounts for the highest installed load.

Table.9.1: Break up of installed lighting load by type of lamp

Type of lamp	Numbers	Load (kW)	%
Flurocent tube light (40W)	586	23.44	72%
Halogen (400W)	3	1.2	4%
Halogen (1000 W)	4	4	12%
Sodium Vapor (250W)	16	4	12%
Total		32.64	

Table.9.2: Break up of installed lighting load in various areas

S.NO	Area	Load (kW)	Percent
1	Plant no-1	3.2	9.8
2	Plant-2	1.6	4.9
3	Plant-3	1.7	5.1
4	Packing area	4.0	12.3
5	Outside area	8.4	25.8
6	Workshop	0.5	1.5
7	Old substation	0.2	0.6
8	Compressor area	0.0	0.1
9	Boiler room	0.2	0.6
10	Genset room	0.0	0.1
11	Filter changing room	0.1	0.2
12	Ac plant	0.6	2.0
13	Sales diispatch area	1.3	3.9
14	Packing section	2.6	8.0
15	Maida stove	1.1	3.4
16	Engg store	0.6	1.8
17	Canteen	0.2	0.7
18	Gallery and toilets	0.2	0.6
19	Incomplete first floor area including R&D	4.2	12.7
20	Incomplete ground floor area	1.9	5.8
	Total	32.6	100.0

9.3. Illumination level

The illumination level measured at different locations and the recommended level of lighting in different areas are given in table 3. The illumination required depends upon the difficulty of the task to be performed and varies widely. It could be seen from the table that generally the illumination provided has been found to be less then recommended levels for various sections of the plant.

Table.9.3: Measured and recommended illumination level

Area	Measured (lux) *	Reccomended (lux)
Chilled water plant 2	44	75-100
Near high speed mixer	22	75-100
Near divider	18	75-100
Near final prover number-1	3	75-100
Near final prover and oven number-1	3	75-100
Near Depanovac	3	75-100
Near moulder number -1	17	75-100
near shifter number -1	8	75-100
Near high speed mixer big	10	75-100
mixiing area general	12	75-100
Rounder plant-1	8	75-100
maida stove	23	75-100
near mixer plant 3	38	75-100
near rounder plant-3	69	75-100
near plant 3 final prover	46	75-100
Near Depanovac plant-3	14	75-100
Prover and oven plant -3	48	75-100
Rounder plant-3	12	75-100
Near bread cooling plant-2	29	75-100
Slicing area	41	75-100
Near plant -1 bread cooling tunnel	20	75-100
Rounder plant-2	21	75-100
Near depanovac plant2	20	75-100
Final prover and ovren	16	75-100
Final prover	14	75-100
Baking tin	22	75-100
Rounder	19	75-100
Supervisors cabin	53	75-100
Workshop	73	75-100
Boiler house	33	75-100
Generator room		75-100
near DG	113	75-100
near LT panel	35	75-100
near main LT panel	33	75-100

AK Rastogis room	70	100-150
Production managers room	60	100-150
Corrider	40	100-150
Safety managers room	110	100-150
Technical division	60	100-150
Sales staff	100	100-150
GMPA process	60	100-150
Mr Mathurs room	70	100-150
Server room	80	100-150
Executive purchage	50	100-150
Adm div	65-90	100-150
Mr Mangotras room	90	100-150
Mr Ramayas room	60	100-150
Accounts hall	90	100-150
R&D	60	100-150

*Measured illumination level correspondence to lights switched on during the time of measuremtns.

9.4. Options for reducing energy consumption

Based on the measurements and observations made during energy audit , the following options have been evolved for reducing energy consumption in lighting.

Use of Energy Efficient tube light

Replacement of the existing 40W lamps installed in the plant and office areas by 28W energy efficient tube light.

Energy Efficient tube light E+ consumes 28W compared to a 53W for a conventional 40 tube light(lamp wattage =40 + Ballast wattage=13W) Therefore there would be a direct savings of 25W per tube light. It also gives a lamp output more then 20% compared to a conventional 40W tube light. Therefore installation of these tube light would also improve the existing illumination levels.

Apart from these it has easy retrofitability also one can use the existing 40W fixture in the retrofittings.

While carrying out these retrofits the plant should acertain that complete retrofitting is done at one time as far as practicable primarily to avoid non uniform distribution of light.

There are 586 number of 40 W fluorescent tube lights installed in the plant and if 50% of these tube lights are replaced with 28 W E+, then

Reduction in lamp wattage (kW) (assuming 24 W reduction in power)	:	7.03
Annual saving in energy (kWh) (@ 15 hours of average operation and 300 days of operation in a year)	:	31644
Annual savings in energy charges (Rs.)	:	107590
Investment required (Rs.)	:	234400
Payback period (years)	:	2.2

Retrofitting existing 40W tube light with 36W Slim tube light

Presently slim tube lights of 36 W and 18 W in 26 mm diameter shell are available in the country. These lamps consume about 8 percent less electricity as compared to the conventional fluorescent tube lights and weigh about 40 percent less. Due to lesser shell diameter (31.6 percent), the lamp also burns `brighter'. The life of slim fluorescent lamp is higher then that for conventional lamps. It was found that conventional tube lights of 40 W each have been installed everywhere in the plant and office areas. By installing a 36 W tube light in place of 40 W lamp, annual energy saving of approximately Rs. 61.2 per lamp could be achieved. There are 586 number of 40 W fluorescent tube lights installed in the plant and if all tube lights are replaced with 36 W tube light, then

Reduction in lamp wattage (kW)	:	2.34
Annual saving in energy (kWh) (@ 15 hours of average operation and 300 days of operation in a year)	:	10548
Annual savings in energy charges (Rs.)	:	35863
Investment required (Rs.)	:	29300
Payback period (months)	:	9.8

Since the payback period is 9.8 months. Which is fairly attractive for such replacements.

Annexure 2.1

Heat balance of Boiler

Table A2.1. Heat balance of boiler

Sl. No.	*Parameter*	*Boiler 2*	*Boiler 3*
1	Steam pressure (kscg)	9	6.5
2	Steam temperature (^{0}C)	179	166.9
3	Moisture in LDO (wt %)	0.3	0.3
4	H_2 in LDO (wt %)	12	12
5	O_2 in flue gas (%)	12	14.1
6	% excess air	133.3	204.3
7	Theoretical air requirement (kg/kg of fuel)	14.1	14.1
8	Total quantity air (kg/kg of fuel)	32.9	42.9
9	Max. CO_2 (%)	15.6	15.6
10	CO_2 in flue gas (%)	6.7	5.1
11	CO (%)	0.0136	0.0073
12	Flue gas temperature (^{0}C)	243	176
13	Ambient temperature (^{0}C)	34	34
14	Feed water temperature (^{0}C)	70	66.8
15	Av. LDO consumption (kg/hr)	14	10.2
16	Sp. gravity of LDO	0.85	0.85
17	Enthalpy of steam (kcal/kg)	663.3	660.55
18	Enthalpy of feed water (kcal/kg)	70	66.8
19	Sensible heat boiler water (Kcal/kg)	14	10.2
20	Feed water TDS (ppm)	50	50
21	Blow down water TDS (ppm)	300	300
22	Blow Rate (ratio)	0.20	0.20
23	Quantity makeup water (kg/hour)*	170.5	128.8
24	Moisture in air at 75% RH & 34^{0}C (kg/kg of air)	0.0255	0.0255
	Heat Losses		
25	Dry flue gas loss (%)	16.88	14.96
26	Heat loss due to CO (%)	0.215	0.116
27	Heat loss due to H2+moist. in fuel (%)	7.16	6.82
28	Heat loss due to moisture in air (%)	0.68	0.54
29	Heat loss due to blow-down (%)	3.35	3.08
30	Structural & unaccounted loss (%)	1	1
31	**Total heat loss (%)**	**29.29**	**26.52**
32	**Thermal efficiency of boiler (%)**	**70.71**	**73.48**

Annexure 2.2

(1)Savings in dry flue gas loss due to optimisation of excess air in boiler

TableA2.2.1. Savings due to optimisation of excess air in boiler

Sl. No.	*Parameter*	*Boiler 2*	*Boiler 3*
1	Existing excess air level (%)	133.3	204.3
2	Existing dry flue gas loss (%)	16.88	14.96
3	Reduced excess air level (%)	20	20
4	Reduced dry flue gas loss (%)	8.68	5.90
5	Saving in loss (%)	8.20	9.06
6	Existing efficiency (useful heat + unaccounted loss) (%)	70.71	73.48
7	Improved efficiency (%)	78.91	82.54
8	Existing LDO consumption (kg/hr)	14	10.2
9	Reduced LDO consumption (kg/hr)	12.5	9.1
10	Saving of LDO (kg/hr)	1.45	1.12
11	Saving of LDO (T) per annum (@ 4320 hours per annum)	6.28	4.84
12	Monetary savings per annum, Rs. lacs (@Rs 14.92/lit LDO)	110320	84900

(2) Savings in dry flue gas loss due to reduction in flue gas temperature in boiler

Table A2.2.2. Savings due to reduction in flue gas temperature boiler

Sl. No.	*Parameter*	*Boiler 2*	*Boiler 3*
1	Existing flue gas temperature (°C)	215	215
2	Existing dry flue gas loss after ex. air optimisation (%)	8.68	5.9
3	Reduced flue gas temperature (°C)	175	180
4	Reduced dry flue gas loss (%)	5.23	5.23
5	Saving in loss (%)	3.45	0.67
6	Existing efficiency (%)	79.24	82.87
7	Improved efficiency (%)	82.69	83.54
8	Existing LDO consumption (kg/hr)	14	10.2
9	Reduced LDO consumption (kg/hr)	13.4	10.1
10	Saving of LDO (kg/hr)	0.6	0.1
11	Saving of LDO (T) per annum (@ 4320 hours per annum)	2.52	0.35
12	Monetary savings per annum, Rs. (@Rs 14.92/lit LDO)	44300	6200

Annexure 2.3

(3) Savings in heat loss due to moisture in air in boiler

Table A2.3. Savings in loss due to moisture in air in boiler

Sl. No.	*Parameter*	*Boiler 2*	*Boiler 3*
1	Existing loss due to moisture in air (%)	0.68	0.54
2	Reduced loss due to moisture in air (%)	0.18	0.18
3	Saving in loss (%)	0.5	0.36
4	Existing efficiency (%)	70.71	73.48
5	Improved efficiency (%)	71.21	73.84
6	Existing LDO consumption (kg/hr)	14	10.2
7	Reduced LDO consumption (kg/hr)	13.90	10.15
8	Saving of LDO (kg/hr)	0.10	0.05
9	Saving of LDO (T) per annum (@ 4320 hours per annum)	0.42	0.21
10	Monetary savings per annum, Rs.(@Rs 14.92/lit LDO)	7450	3770

Annexure 2.4

(4) Savings in heat loss due to hydrogen and moisture in fuel in boiler

Table A2.4. Savings in loss due to hydrogen and moisture in fuel in boiler

Sl. No.	Parameter	Boiler 2	Boiler 3
1	Existing loss due to H_2 and moisture in fuel (%)	7.16	6.82
2	Reduced loss due to H_2 and moisture in fuel (%)	6.74	6.74
3	Saving in loss (%)	0.42	0.08
4	Existing efficiency (%)	79.24	82.87
5	Improved efficiency (%)	79.66	82.95
6	Existing LDO consumption (kg/hr)	14	10.2
7	Reduced LDO consumption (kg/hr)	13.93	10.19
8	Saving of LDO (kg/hr)	0.07	0.01
9	Saving of LDO (T) per annum (@ 4320 hours per annum)	0.32	0.04
10	Monetary savings per annum, Rs.(@Rs 14.92/lit LDO)	5600	750

Annexure 2. 5

(5) Saving in heat loss due to blowdown in boiler

Table A2.5. Savings in loss due to blowdown in boiler

Sl. No.	*Parameter*	*Boiler 2*	*Boiler 3*
1	Loss due to blowdown (present) (%)	3.35	3.08
2	Reduced loss due to blowdown (optimised) (%)	0.24	0.22
3	Saving in loss (%)	3.11	2.86
4	Existing efficiency (%)	83.28	83.65
5	Improved efficiency (%)	86.39	86.51
6	Existing LDO consumption (kg/hr)	14	10.2
7	Reduced LDO consumption (kg/hr)	13.50	9.86
8	Saving of LDO (kg/hr)	0.50	0.34
9	Saving of LDO (T) per annum (@ 4320 hours per annum)	2.18	1.46
10	Monetary savings per annum, Rs.(@Rs 14.92/lit LDO)	38220	25570

Annexure 3.1

Specific spot of high temperature on different surfaces

The actual temperature of individual surface of two ovens was monitored, while it is in the operating condition and associated systems are also operating. The number of surface temperature reading was 1-20. Hence, the average temperature figure was used for the heat loss calculation of oven surfaces. Table A3.1 shows the temperature level of different surface of two operating ovens in the unit.

Table A3.1. Temperature level of different surface of two ovens

Sl. no.	*Location*	*Temperature (°C)*
	Oven 1	
1	LHS front segment	74.3
2	RHS segment	71.0
3	Top	67.0
	Oven 2	
4	LHS from segment	74.3
5	RHS front segment	71.0
6	Top	67.0

Annexure 3.2

Heat balance of two Ovens

Table A3.2. Heat balance of Oven No. 1 and 2

Sl. No.	*Parameter*	*Oven 1*	*Oven 2*
1	LDO firing rate (kg/hr)	28.1	19.6
	Avg. energy input by LDO (kcal/hr)	2866200	199920
2	Sp. Gravity of LDO (kg/L)	0.85	0.85
3	Gross calorific value of LDO (kcal/kg)	10200	10200
4	Percentage of moisture removed/retained (%)	4.4/10.7	14.5/0.2
5	Mass of bread + moisture at outlet (kg/hr)	752	480.2
6	Actual quantity of moisture (kg/hr)		
	- removed	34.9	95.5
	- retained	83.9	10.1
7	Avg. temp. of baking section (°C) *	265	174.5
8	Sensible heat of water at peak temperature (°C)	265	250
9	Qty. of moisture consumed by bread before baking(kg/hour)	118.80	82.6
10	Actual weight of bread at outlet (kg/hr)	668.1	479
11	Avg. baking temp. (designed) of bread (°C)	265	250

12	Temp. of bread at inlet (°C)	36.2	37
13	Avg. sp. heat of bread (kcal/kg °C)	0.75	0.75
14	Ambient temperature (°C)	34.3	34.3
15	Moisture in fuel (wt %)	0.3	0.3
16	H2 in fuel (wt %)	12.0	12.0
17	Existing oxygen in flue gas (%)	9.95	7.5
18	Excess air (%)	90	55.6
19	Theo. air requirement (kg/kg of fuel)	14.1	14.1
20	Total quantity of air (kg/kg of fuel)	26.8	21.9
21	Maximum CO_2 (%)	15.6	15.6
22	CO_2 in flue gas (%)	8.2	10.0
23	CO (%)	0.074	0.025
24	Flue gas temperature (°C)	308	189
25	Moisture in air (kg/kg of air)		
	- at 76% RH and 34.3 deg. C	0.0258	0.0258
	Heat losses		
26	Heat taken by bread (%)	40.07	28.39
27	Heat loss in dry flue gas (%)	18.01	8.33
28	Heat loss due to CO (%)	1.2	0.40
29	Heat loss due to H_2+moisture in fuel (%)	7.49	6.88
30	Heat loss due to moisture in air (%)	0.77	0.31
31	Heat (overall) in moisture removal (%)	8.19	27.1
32	Heat (overall) retained in moisture (%)	7.77	0.15
33	Heat loss through structure (%)	8.19	16.23
34	Total heat distributed (%)	99.97	96.2
35	Unacconted heat loss (%)**	0.03	3.8

Annexure 3.3

(1) Savings in dry flue gas loss due to optimisation of excess air in ovens

TableA3.3.1. Savings due to optimisation of excess air in Oven No. 1 and 2.

Sl. No.	*Parameter*	*Oven 1*	*Oven 2*
1	Existing excess air level (%)	90	55.6
2	Existing dry flue gas loss (%)	18.01	8.33
3	Reduced excess air level (%)	45	45
4	Reduced dry flue gas loss (%)	13.74	7.77
5	Saving in loss (%)	4.3	0.56
6	Existing efficiency (useful heat + unaccounted loss) (%)	47.87	32.34
7	Improved efficiency (%)	52.1	32.9
8	Existing LDO consumption (kg/hr)	28.1	19.6
9	Reduced LDO consumption (kg/hr)	25.8	19.3

10	Saving of LDO (kg/hr)	2.30	0.33
11	Saving of LDO (T) per annum (@ 7487442/ 6492855 sloves per annum)	14.26	1.80
12	Monetary savings per annum, Rs. (@Rs 14.92/lit LDO)	250280	31670

(2)Savings in dry flue gas loss due to reduction in flue gas temperature and provision of hot combustion air in ovens

Table A3.3.2. Savings due to reduction in flue gas temperature Oven No. 1 and 2.

Sl. No.	*Parameter*	*Oven 1*	*Oven 2*
1	Existing flue gas temperature (°C)	308	189
2	Existing dry flue gas loss after ex. air optimization (%)	13.74	7.77
3	Reduced flue gas temperature (°C)	160	160
4	Reduced dry flue gas loss (%)	6.81	6.31
5	Saving in loss (%)	6.93	1.46
6	Existing efficiency (useful heat + unaccounted loss) (%)	52.32	32.98
7	Improved efficiency (%)	59.25	34.44
8	Existing LDO consumption (kg/hr)	28.1	19.6
9	Reduced LDO consumption (kg/hr)	24.8	18.8
10	Saving of LDO (kg/hr)	3.3	0.83
11	Saving of LDO (T) per annum	20.36	4.49
12	Monetary savings per annum, Rs. (@Rs 14.92/lit LDO)	357450	78870

Annexure 3.4

(4) Savings in heat loss in ovens due to hydrogen and moisture in fuel

Table.A3.4. Savings in heat loss in ovens due to hydrogen and moisture in fuel

Sl. No.	*Parameter*	*Oven 1*	*Oven 2*
1	Existing loss due to H_2 and moisture in fuel (%)	7.49	6.88
2	Reduced loss due to H_2 and moisture in fuel (%)	6.79	6.74
3	Saving in loss (%)	0.7	0.14
4	Existing efficiency (%)	52.32	32.98
5	Improved efficiency (%)	53.02	33.12
6	Existing LDO consumption (kg/hr)	28.1	19.6
7	Reduced LDO consumption (kg/hr)	27.7	19.5
8	Saving of LDO (kg/hr)	0.4	0.1
9	Saving of LDO (T) per annum	2.30	0.45
10	Monetary savings per annum, Rs. (@Rs 14.92/lit LDO)	40350	7860

Annexure 3.5

(3) Savings in heat loss in ovens due to moisture in air

Table.A3.5. Savings in heat loss in ovens due to moisture in air

Sl. No.	*Parameter*	*Oven 1*	*Oven 2*
1	**Existing loss due to moisture in air (%)**	**0.77**	**0.31**
2	**Reduced loss due to moisture in air (%)**	**0.24**	**0.22**
3	**Saving in loss (%)**	**0.53**	**0.09**
4	**Existing efficiency (%)**	**47.87**	**32.34**
5	**Improved efficiency (%)**	**48.40**	**32.41**
6	**Existing LDO consumption (kg/hr)**	**28.1**	**19.6**
7	**Reduced LDO consumption (kg/hr)**	**27.79**	**19.56**
8	**Saving of LDO (kg/hr)**	**0.31**	**0.04**
10	**Monetary savings per annum, Rs. (@Rs 14.92/lit LDO)**	**33470**	**4020**

Annexure 3.6

Heat balance of two Final Provers

Table.A3.6. Heat balance of two final provers

Parameter	Prover 1	Prover 2
Energy input		
- FLUE GASES, kcal/ hr	55053.97	22279.085
Effective input (65%), kcal/ hr	35785.08	14481.405
- STEAM, kcal/ hr	72336.2	78782
TOTAL kcal/ hr	**108121.3**	**93263.4**
Bread temperature for final proof	40	41
Sens.heat of water at proof temp.(kcal/kg)	40	41
Qty. of moisture added (kg/hour)	24	15
Heat in retained mosture(%),mean	**0.89**	**0.66**
Actual mass of bread at outlet (kg/hr)	668.1	479
Temp. of bread at inlet (OC)	34.3	34.3
Sp. heat of bread (kcal/ kg OC)	0.75	0.75
Heat absorbed by bread (kcal/hr)	2856.13	2406.98
(%)	**2.64**	**2.58**
Avg. mass of tin for bread (kg/hr)	1528	1119.1
Avg. tin temp. at outlet (OC)	36.2	37
Temp. of tin at inlet (OC)	34.3	34.3
Sp. heat of tin/ MS (kca/ kg OC)	0.095	0.095
Heat absorbed by tin (kcal/hr)	275.8	287.0
(%)	**0.26**	**0.31**
Structural heat loss (%)	**3.5**	**7.07**
Heat due to condensate (%)	**0.224**	**0.283**
Efficiency + Unaccounted loss (%)	**92.49**	**89.1**

Annexure 3.7

Heat balance of Cooling tunnel 1

Table.A3.7. Heat balance of cooling tunnel 1

Parameter	Level
Mass of bread inside cooler (kg/batch)	768
Cooling time per batch (hrs)	1.42
Loading on tunnel (%)	90
Actual mass of bread at outlet (kg/hr)	488
Temp. of bread at inlet (0C)	89
Temp. of bread at outlet (0C)	19
Sp. heat of bread (kca/ kg 0C)	0.75
Heat dissipated by bread (kcal/hr)	**25615**
Avg. mass of trolley (kg)	14.5
Avg. mass of trolley (kg/batch)	116
Actual weight of trolley inside (kg/hr)	81.9
Avg. trolley temp. at outlet (0C)	19
Temp. of trolley at inlet (0C)	34.3
Sp. heat of MS trolley (kca/ kg 0C)	0.095
Heat dissipated by trolley (kcal/hr)	**119**
Temp.of cold air (0C)	19
Setting of temperature (0C)	27.4
Qty. of air circulated (cfm)	4500
(m3/ hr)	7641
Density of air at 20-27^{0}C (kg/m3)	1.177
Qty. of air circulated (kg/hour)	8993
Sp. heat of air at 40-50^{0}C (kcal/kg)	0.24
Heat absorbed by circulating air (kcal/hr)	**18131**
(%)	
Sens.heat of water at cooling temp.(kcal/kg)	27.4
Moisture in air at 77% RH &28^{0}C (kg/kg of air)	0.0195
Qty. of moisture added (kg/hour)	175
Heat in retaiined by mosture (kcal/hr)	**4805**
(%)	
Structural heat gain (kcal/hr)	**1533**
Total heat dissipation by breads/ loaves, trolleys&structure (kcal/ hr)	27267
Total heat absorbed by circulating air and mosture (kcal/hr)	22936
Unacconted heat gain (kcal/hr)	4331
(%)**	15.9

** include heat gain due to air ingress

Annexure 3.8

Replacement of aluminium blades of Cooling tunnel (No.1) fans with hollow FRP blades

Table.A3.8. Replacement of aluminium blades of cooling tunnel fans with hollow FRP blades

Parameter	No.1
Number of fan in cooling tunnel	1
Installed capacity of motor for the fan in cooling tower (hp)	3
(kW)	2.238
Assuming, avg. operating load(65%) on the fan motor (kW)	1.455
Anticipated savings by using hollow FRP blades (%)	15
Actual Savings (kW)	0.218
Actual working hours (hrs) per annum *	6196
Savings (kWh) per annum	1352
Annual monetary savings, Rs. (@Rs.3.4/kWh)	4600
Estimated investment (Rs)	12000
Simple pay back period (months)	31

Annexure 4.1

Estimation of total compressed air leakage in plant (Using compressor #1)

Table A4.1. Savings in loss due to compressed air leakage

Sl. No.	*Parameter*		*Level*
1	Initial pressure in the in-built gauge	-	9.3 kg/cm^2 (g)
2	Final pressure in the in-built gauge	-	10.5 kg/cm^2 (g)
3	Volume of air receiver+pipe+others	-	0.3040 m^3
4	Free air delivery of compressor (designed)	-	0.57 m^3/min
5	Average time taken to fall in air pressure	-	0.93 minutes
6	Average time to built up air pressure	-	1.37 minutes
7	Compressed air leakage	-	40.5%
8	Compressed air leakage (based on actual FAD)	-	0.23 m^3/min (~ 8 cfm)
9	Specific power consumption (based on actual FAD)	-	5.26 kW/m^3/min
10	Loss due to leakage	-	1.2kW
11	Electrical savings per annum	-	5016 Kwh/year
12	Monetary savings per annum	-	Rs. 17060

Annexure 5.1

Replacement of aluminium blades of cooling tower fan with hollow FRP blades

Table A 5.1. Savings due to replacement of aluminium blades of cooling tower

Sl. no.	*Parameter*	*CT 1*	*CT 3*
1	Number of fan in cooling tower	1	1
2	Installed capacity of motor for the fan in cooling tower (kW)	0.746	1.49
3	Assuming, average operating load (65%) on the fan motor (kW)	0.466	0.93
4	Anticipated savings by using hollow FRP blades (%)	15	15
5	Actual Savings (kW)	0.070	0.140
6	Assumed working hours (hrs) per annum *	7200	7200
7	Savings (kWh) per annum	504	1007
8	Monetary savings per annum, Rs. (@ Rs. 3.4/kWh)	1710	3420
9	Estimated investment (Rs)	9000	12000
10	Simple pay back period (months)	63.1	42.1

Annexure 5.2

nstallation of CT-ENSAVER+ (thermostatic controller) with cooling tower (No.) serving for air compressors, chiller & chilling plant of 100TR

y installing the CT-ENSAVER+ (thermostatic controller) for fan motor circuit in cooling ower No. 1, annual savings of the fan is given in A5.3 respectively.

Table A5.3. Savings due to installation of CT-ENSAVER+ (thermostatic controller)

Sl. No	*Parameter*	*CT 1*	*CT 3*
1	Number of fan in cooling tower	1	1
2	Installed capacity of motor for the fan in cooling tower (kW)	0.746	1.49
3	Assuming, average operating load (62.5%) on the fan motor (kW)	0.466	0.933
4	Assumed working hours reduction (as give in table A2 above) per annum *	3480	3480
5	Savings (kWh) per annum	1623	3245
6	Annual monetary savings, Rs.(@ Rs.3.4/ kWh)	5520	11030
7	Estimated investment (Rs)	18000	18000
8	Simple pay back period (months)	39,2	19/6

Annexure 8.1

Transmission Drives

Transmission drives, such as pulleys and belts, and gears transit mechanical rotational power from the prime mover shaft to the shaft connected to the mechanical load such as a compressor, blower or a fan. The simplest form of transmission drive is the belt drive which is least expensive, light and quiet in operation. The belt drive transmits power solely by the frictional grip between the belt(s) and the pulley. The belts consist of tension strands which serve to absorb the tractional forces operating in the belts, which are covered with an elastomer. The elastomer holds the strands together and provides surface friction for power transmission.

Generally, V-belts have been used in belt drives, but lately new materials have made it possible to produce flat belts with better performance characteristics. Unlike the V-belt that develops additional lateral frictional forces, the flat belt develops only the tangential forces. This reduces the stress on the (flat) belt and results in lower heat generation due to lower lateral compression and elongation. Moreover, the flat belt is free from the effect of heating at the edges that results in hardening of rubber and reduction in the frictional grip. The flat belt combines the outstanding properties of man-made and natural materials - nylon (super polyamide) and chrome leather or elastomer. Nylon, which has extraordinary tensile strength and very high modulus of elasticity, is particularly valuable in transmitting very high loads without stretching. Chrome leather has high co-efficient of friction even when oily and is resistant to abrasion. The elastomer used is specially suited for dry operations and for high speed tangential belts in textile industry at speeds up to 100 m/s. As a rule of thumb, it can be said that above a belt speed of 10 m/s, flat belts are equivalent to V-belts and that above 30 m/s they are superior. However, above 40 m/s they have a distinction of their own. In contrast with V-belts they can tolerate high bending frequencies and very high load fluctuations. Their service life is also longer. The average power transmission efficiency of flat belts is 98 percent as compared to 86 percent for V-belt drives.

Summary of advantages

The outstanding characteristics which make flat belts the most efficient form for power transmission are:

a. Elastic power transmission at 98 percent efficiency, as compared to 85-88 percent for V-belts.

b. Narrower pulley widths, i.e., 25/50 percent of those required for V-belts. Jack-shaft arrangement is eliminated in some drives.

c. Higher belt velocities of 60 m/sec are feasible compared to 25 m/sec. for V-belts. This enables use of standard high rpm motors, saving considerably on initial capital investment.

d. Modern flat belts do not elongate and thus no shortening or retensioning is required. Consequently, they can be used on fixed centre drives.

e. The extraordinary tensile strength, high modules of elasticity and very high frictional coefficient of the belt surface make short centred, high-ratio drives possible, with pulley rims almost touching and lower shaft loads.

f. Longer life of 20-50 percent than V-belt drives.